NLP Stock Volatility Prediction

1. Load Libraries
2. Preprocess dataframe
3. Load Word Embeddings
4. Train Models
5. Model Evaluation
6. Continue Training for More Epochs

1. Load Libraries

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

```
Mounted at /content/drive
```

```python
# import required libraries
import pandas as pd
import numpy as np
import re
import matplotlib.pyplot as plt
import pickle
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, MultiLabelBinarizer

# Deep Learning Libraries
import tensorflow as tf
import keras
from tensorflow.keras.models import Model, load_model
from tensorflow.keras.layers import Dense, Dropout, GRU, Input, Embedding, Bidirectional
from tensorflow.keras.layers import Flatten, Conv1D, MaxPooling1D, GlobalMaxPooling1D, BatchNormalization
from tensorflow.keras.layers import concatenate
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras import backend as K
from tensorflow.keras.metrics import AUC
from tensorflow.keras.utils import multi_gpu_model

config = tf.compat.v1.ConfigProto()
config.gpu_options.allow_growth = True

#!pip install keras==2.3.0
#from tensorflow.python.keras.layers import CuDNNGRU

#sess_config.gpu_options.allow_growth = True
#from keras.backend.tensorflow_backend import set_session
#import tensorflow.compat.v1 as tf
#tf.disable_v2_behavior()
```

```python
# check the cpu and gpu being used
from tensorflow.python.client import device_lib
print(device_lib.list_local_devices())
```

```
[name: "/device:CPU:0"
device_type: "CPU"
memory_limit: 268435456
locality {
}
incarnation: 11758833143096406305
, name: "/device:XLA_CPU:0"
device_type: "XLA_CPU"
memory_limit: 17179869184
locality {
}
incarnation: 9718225536536755501
physical_device_desc: "device: XLA_CPU device"
, name: "/device:XLA_GPU:0"
device_type: "XLA_GPU"
memory_limit: 17179869184
locality {
}
incarnation: 4972091611459687244
physical_device_desc: "device: XLA_GPU device"
, name: "/device:GPU:0"
device_type: "GPU"
memory_limit: 15473775744
locality {
  bus_id: 1
  links {
  }
}
incarnation: 10441743454703665301
physical_device_desc: "device: 0, name: Tesla V100-SXM2-16GB, pci bus id: 0000:00:04.0, compute capability: 7.0"
]
```

2. Preprocess dataframe

```python
# read data
df = pd.read_csv("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/lemmatized_text.csv")
```

```python
df.release_date.value_counts()
```

```
2017-07-27 07:37:05    2
2017-10-02 07:38:03    1
2016-06-15 16:05:32    1
2016-08-04 06:24:56    1
2018-02-28 10:34:51    1
                      ..
2016-08-03 16:16:09    1
2015-04-20 21:44:20    1
2014-11-20 16:01:31    1
2016-01-13 11:28:06    1
2016-04-26 07:05:39    1
Name: release_date, Length: 1650, dtype: int64
```

```python
mlb = MultiLabelBinarizer()
df = df.join(pd.DataFrame(mlb.fit_transform(df.pop('items')), columns=mlb.classes_,), sort=False, how="left")
```

```python
df.isna().sum()
```

```
Unnamed: 0            0
Unnamed: 0.1          0
Unnamed: 0.1.1        0
ticker                0
cik                   0
doc_name              0
txt_link              0
GICS Sector           0
GICS Sub Industry     0
text                  0
release_date          0
price_change         42
vix                   1
rm_week              39
rm_month             34
rm_qtr               41
rm_year              56
processed_text        0
text_len              0
signal                0
                      0
'                     0
,                     0
.                     0
0                     0
1                     0
2                     0
3                     0
4                     0
5                     0
6                     0
7                     0
8                     0
9                     0
I                     0
[                     0
]                     0
e                     0
m                     0
t                     0
dtype: int64
```

```python
# get rid of rows that has missing values
df.dropna(subset=['vix', 'rm_week', 'rm_month', 'rm_qtr', 'rm_year'], inplace=True)
```

```python
#### Define number of words, and embedding dimensions
max_words = 34603
embed_dim = 100

def load_embeddings(vec_file):
    print("Loading Glove Model")
    f = open(vec_file, 'r')
    model = {}
    for line in f:
        splitLine = line.split()
        word = splitLine[0]
        embedding = np.array([float(val) for val in splitLine[1:]])
        model[word] = embedding
    print("Done. {} words loaded!".format(len(model)))
    return model

def tokenize_and_pad(docs, max_words=max_words):
    global t
    t = Tokenizer()
    t.fit_on_texts(docs)
    docs = pad_sequences(sequences = t.texts_to_sequences(docs), maxlen = max_words, padding = 'post')
    global vocab_size
    vocab_size = len(t.word_index) + 1

    return docs

def oversample(X, docs, y):
    # Get number of rows with imbalanced class
    target = y.sum().idxmax()
    n = y[target].sum()
    # identify imbalanced targets
    imbalanced = y.drop(target, axis=1)
    #For each target, create a dataframe of randomly sampled rows, append to list
    append_list =  [y.loc[y[col]==1].sample(n=n-y[col].sum(), replace=True, random_state=20) for col in imbalanced.columns]
    append_list.append(y)
    y = pd.concat(append_list, axis=0)
    # match y indexes on other inputs
    X = X.loc[y.index]
    docs = pd.DataFrame(docs_train, index=y_train.index).loc[y.index]
    assert (y.index.all() == X.index.all() == docs.index.all())
    return X, docs.values, y
```

```python
# Separate into X and Y
cols = ['GICS Sector', 'vix', 'rm_week', 'rm_month', 'rm_qtr', 'rm_year']
cols.extend(list(mlb.classes_))

X = df[cols]
docs = df['processed_text']
y = df['signal']

# Get Dummies
docs = tokenize_and_pad(docs)
X = pd.get_dummies(columns = ['GICS Sector'], prefix="sector", data=X)
y = pd.get_dummies(columns=['signal'], data=y)

aux_shape = len(X.columns)
```

```python
# Split into train, validation and test data
X_train, X_test, y_train, y_test, docs_train, docs_test = train_test_split(X, y, docs,
                                                                            stratify=y,
                                                                            test_size=0.3,
                                                                            random_state=20)

X_val, X_test, y_val, y_test, docs_val, docs_test = train_test_split(X_test, y_test, docs_test,
                                                                      stratify=y_test,
                                                                      test_size=0.5,
                                                                      random_state=20)
```

```python
cont_features = ['vix', 'rm_week', 'rm_month', 'rm_qtr', 'rm_year']
aux_features = cont_features + [item for item in mlb.classes_]
ss = StandardScaler()
X_train[cont_features] = ss.fit_transform(X_train[cont_features])
X_val[cont_features] = ss.transform(X_val[cont_features])
X_test[cont_features] = ss.transform(X_test[cont_features])

X_train, docs_train, y_train = oversample(X_train, docs_train, y_train)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:4: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  after removing the cwd from sys.path.
/usr/local/lib/python3.6/dist-packages/pandas/core/indexing.py:1734: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  isetter(loc, value[:, i].tolist())
```

3. Load Word Embeddings

```python
embeddings_index = load_embeddings("/content/drive/My Drive/NLP-Stock-Prediction-master/glove.6B.100d.txt")
```

```
Loading Glove Model
Done. 400000 words loaded!
```

```python
words_not_found = []

embedding_matrix = np.zeros((vocab_size, embed_dim))
for word, i in t.word_index.items():
    embedding_vector = embeddings_index.get(word)
    if embedding_vector is not None:
        # words not found in embedding index will be all-zeros.
        embedding_matrix[i] = embedding_vector
    else:
        words_not_found.append(word)
print('number of null word embeddings: %d' % np.sum(np.sum(embedding_matrix, axis=1) == 0))
```

```
number of null word embeddings: 1565176
```

```python
# Save data
np.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/docs_train.npy",docs_train)
np.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/docs_val.npy",docs_val)
np.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/docs_test.npy",docs_test)

X_train.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/X_train.pkl")
X_val.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/X_val.pkl")
X_test.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/X_test.pkl")

y_train.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/y_train.pkl")
y_val.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/y_val.pkl")
y_test.to_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/y_test.pkl")

np.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/embedding_matrix.npy", embedding_matrix)
```

4. Build & Train Models

```python
def build_model(output_classes, architecture, vaux_shape=aux_shape, vvocab_size=vocab_size, vembed_dim=embed_dim, embedding_matrix=embedding_matrix, max_seq_len=max_words):

    #with tf.device('/cpu:0'):
    main_input= Input(shape=(max_seq_len,), name='doc_input')
    main = Embedding(input_dim = vocab_size,
                     output_dim = embed_dim,
                     weights = [embedding_matrix],
                     input_length = max_seq_len,
                     trainable=False)(main_input)

    if architecture == 'mlp':
        # Densely Connected Neural Network (Multi-Layer Perceptron)
        main = Dense(32, activation='relu')(main)
        main = Dropout(0.2)(main)
        main = Flatten()(main)
    elif architecture == 'cnn':
        # 1-D Convolutional Neural Network
        main = Conv1D(64, 3, strides=1, padding='same', activation='relu')(main)
        #Cuts the size of the output in half, maxing over every 2 inputs
        main = MaxPooling1D(pool_size=3)(main)
        main = Dropout(0.2)(main)
        main = Conv1D(32, 3, strides=1, padding='same', activation='relu')(main)
        main = GlobalMaxPooling1D()(main)
    elif architecture == 'rnn':
        main = Bidirectional(layer=GRU(32, return_sequences=False), merge_mode='concat')(main)
        main = BatchNormalization()(main)
    elif architecture =="rnn_cnn":
        main = Conv1D(64, 5, padding='same', activation='relu')(main)
        main = MaxPooling1D()(main)
        main = Dropout(0.2)(main)
        main = Bidirectional(layer=GRU(32,return_sequences=False),merge_mode='concat')(main)
        main = BatchNormalization()(main)

    else:
        print('Error: Model type not found.')

    auxiliary_input = Input(shape=(aux_shape,), name='aux_input')
    x = concatenate([main, auxiliary_input])
    x = Dense(32, activation='relu')(x)
    x = Dropout(0.2)(x)
    x = Dense(32, activation='relu')(x)
    x = Dense(32, activation='relu')(x)
    main_output = Dense(output_classes, activation='softmax', name='main_output')(x)
    model = Model(inputs=[main_input, auxiliary_input], outputs=[main_output], name=architecture)

    #sgd = SGD(lr=0.01, decay=1e-6, momentum=0.9, nesterov=True)
    #model = multi_gpu_model(model, gpus=2)
    model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy', 'AUC'])

    return model


def gen():
    print('generator initiated')
    idx = 0
    while True:
        yield [docs_train[:32], X_train[:32]], y_train[:32]
        print('generator yielded a batch %d' % idx)
        idx += 1
```

```python
model_dict = dict()
```

```python
mlp = build_model(3, "mlp")

model_dict["mlp"] = mlp.fit([docs_train, X_train], y_train, batch_size=64, epochs=10, verbose=1, validation_data = ([docs_val, X_val], y_val))

mlp.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/mlp.hdf5")
with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/mlp.pkl', 'wb') as file_pi:
  pickle.dump(model_dict["mlp"].history, file_pi)
```

```
Epoch 1/10
37/37 [==============================] - 6s 165ms/step - loss: 1.0867 - accuracy: 0.4230 - auc: 0.6125 - val_loss: 1.0529 - val_accuracy: 0.5672 - val_auc: 0.7156
Epoch 2/10
37/37 [==============================] - 6s 156ms/step - loss: 0.9119 - accuracy: 0.6486 - auc: 0.8250 - val_loss: 1.3063 - val_accuracy: 0.3739 - val_auc: 0.6504
Epoch 3/10
37/37 [==============================] - 6s 156ms/step - loss: 0.6840 - accuracy: 0.7559 - auc: 0.9106 - val_loss: 1.8054 - val_accuracy: 0.6345 - val_auc: 0.7616
Epoch 4/10
37/37 [==============================] - 6s 156ms/step - loss: 0.5278 - accuracy: 0.7795 - auc: 0.9302 - val_loss: 2.3256 - val_accuracy: 0.6050 - val_auc: 0.7302
Epoch 5/10
37/37 [==============================] - 6s 155ms/step - loss: 0.5004 - accuracy: 0.8027 - auc: 0.9452 - val_loss: 2.7536 - val_accuracy: 0.6261 - val_auc: 0.7447
Epoch 6/10
37/37 [==============================] - 6s 152ms/step - loss: 0.4457 - accuracy: 0.8121 - auc: 0.9491 - val_loss: 2.5481 - val_accuracy: 0.6261 - val_auc: 0.7511
Epoch 7/10
37/37 [==============================] - 6s 152ms/step - loss: 0.4053 - accuracy: 0.8202 - auc: 0.9558 - val_loss: 3.0857 - val_accuracy: 0.5966 - val_auc: 0.7407
Epoch 8/10
37/37 [==============================] - 6s 153ms/step - loss: 0.4359 - accuracy: 0.8198 - auc: 0.9558 - val_loss: 2.8573 - val_accuracy: 0.5882 - val_auc: 0.7264
Epoch 9/10
37/37 [==============================] - 6s 153ms/step - loss: 0.4059 - accuracy: 0.8190 - auc: 0.9564 - val_loss: 2.7048 - val_accuracy: 0.5882 - val_auc: 0.7278
Epoch 10/10
37/37 [==============================] - 6s 152ms/step - loss: 0.4068 - accuracy: 0.8228 - auc: 0.9587 - val_loss: 2.9846 - val_accuracy: 0.5630 - val_auc: 0.7109
```

```python
cnn = build_model(3, "cnn")

model_dict["cnn"] = cnn.fit([docs_train, X_train], y_train, batch_size=64, epochs=10, verbose=1, validation_data = ([docs_val, X_val], y_val))

cnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/cnn.hdf5")
with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/cnn.pkl', 'wb') as file_pi:
    pickle.dump(model_dict["cnn"].history, file_pi)
```

```
Epoch 1/10
37/37 [==============================] - 7s 196ms/step - loss: 1.0957 - accuracy: 0.3625 - auc: 0.5328 - val_loss: 1.1090 - val_accuracy: 0.3109 - val_auc: 0.4924
Epoch 2/10
37/37 [==============================] - 7s 186ms/step - loss: 1.0802 - accuracy: 0.3874 - auc: 0.5787 - val_loss: 1.1044 - val_accuracy: 0.3235 - val_auc: 0.5070
Epoch 3/10
37/37 [==============================] - 7s 182ms/step - loss: 1.0570 - accuracy: 0.4530 - auc: 0.6346 - val_loss: 1.1052 - val_accuracy: 0.3319 - val_auc: 0.5141
Epoch 4/10
37/37 [==============================] - 7s 182ms/step - loss: 1.0464 - accuracy: 0.4758 - auc: 0.6515 - val_loss: 1.0575 - val_accuracy: 0.4790 - val_auc: 0.6417
Epoch 5/10
37/37 [==============================] - 7s 182ms/step - loss: 1.0223 - accuracy: 0.5054 - auc: 0.6787 - val_loss: 1.0091 - val_accuracy: 0.6008 - val_auc: 0.7157
Epoch 6/10
37/37 [==============================] - 7s 181ms/step - loss: 1.0004 - accuracy: 0.5079 - auc: 0.6937 - val_loss: 1.0742 - val_accuracy: 0.4370 - val_auc: 0.6023
Epoch 7/10
37/37 [==============================] - 7s 182ms/step - loss: 0.9810 - accuracy: 0.5199 - auc: 0.7109 - val_loss: 0.9717 - val_accuracy: 0.6050 - val_auc: 0.7359
Epoch 8/10
37/37 [==============================] - 7s 181ms/step - loss: 0.9496 - accuracy: 0.5491 - auc: 0.7339 - val_loss: 0.9841 - val_accuracy: 0.5420 - val_auc: 0.7125
Epoch 9/10
37/37 [==============================] - 7s 184ms/step - loss: 0.9313 - accuracy: 0.5568 - auc: 0.7481 - val_loss: 0.9548 - val_accuracy: 0.5672 - val_auc: 0.7326
Epoch 10/10
37/37 [==============================] - 7s 182ms/step - loss: 0.9102 - accuracy: 0.5671 - auc: 0.7616 - val_loss: 0.9935 - val_accuracy: 0.5504 - val_auc: 0.7000
```

```python
rnn = build_model(3, "rnn")

model_dict["rnn"] = rnn.fit([docs_train, X_train], y_train, batch_size=32, epochs=10, verbose=1, validation_data = ([docs_val, X_val], y_val))

rnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn.hdf5")
with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn.pkl', 'wb') as file_pi:
    pickle.dump(model_dict["rnn"].history, file_pi)
```

```
Epoch 1/10
73/73 [==============================] - 146s 2s/step - loss: 1.1023 - accuracy: 0.3754 - auc: 0.5433 - val_loss: 1.0933 - val_accuracy: 0.3151 - val_auc: 0.5518
Epoch 2/10
73/73 [==============================] - 144s 2s/step - loss: 1.0665 - accuracy: 0.4269 - auc: 0.6090 - val_loss: 1.0611 - val_accuracy: 0.4496 - val_auc: 0.6286
Epoch 3/10
73/73 [==============================] - 144s 2s/step - loss: 1.0328 - accuracy: 0.4715 - auc: 0.6580 - val_loss: 1.0143 - val_accuracy: 0.5084 - val_auc: 0.6780
Epoch 4/10
73/73 [==============================] - 143s 2s/step - loss: 1.0079 - accuracy: 0.4865 - auc: 0.6802 - val_loss: 1.0246 - val_accuracy: 0.4874 - val_auc: 0.6632
Epoch 5/10
73/73 [==============================] - 144s 2s/step - loss: 0.9829 - accuracy: 0.5049 - auc: 0.7013 - val_loss: 1.0059 - val_accuracy: 0.5252 - val_auc: 0.6826
Epoch 6/10
73/73 [==============================] - 143s 2s/step - loss: 0.9657 - accuracy: 0.5199 - auc: 0.7187 - val_loss: 1.0113 - val_accuracy: 0.5042 - val_auc: 0.6809
Epoch 7/10
73/73 [==============================] - 143s 2s/step - loss: 0.9577 - accuracy: 0.5380 - auc: 0.7259 - val_loss: 0.9668 - val_accuracy: 0.5630 - val_auc: 0.7238
Epoch 8/10
73/73 [==============================] - 143s 2s/step - loss: 0.9365 - accuracy: 0.5581 - auc: 0.7403 - val_loss: 0.9593 - val_accuracy: 0.5420 - val_auc: 0.7172
Epoch 9/10
73/73 [==============================] - 143s 2s/step - loss: 0.9138 - accuracy: 0.5731 - auc: 0.7553 - val_loss: 0.8972 - val_accuracy: 0.5756 - val_auc: 0.7716
Epoch 10/10
73/73 [==============================] - 143s 2s/step - loss: 0.9094 - accuracy: 0.5744 - auc: 0.7593 - val_loss: 0.9649 - val_accuracy: 0.5504 - val_auc: 0.7182
```

```python
rnn_cnn = build_model(3, "rnn_cnn")

model_dict["rnn_cnn"] = rnn_cnn.fit([docs_train, X_train], y_train, batch_size=32, epochs=10, verbose=1, validation_data = ([docs_val, X_val], y_val))

rnn_cnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_cnn.hdf5")
with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn_cnn.pkl', 'wb') as file_pi:
    pickle.dump(model_dict["rnn_cnn"].history, file_pi)
```

```
Epoch 1/10
73/73 [==============================] - 77s 1s/step - loss: 1.0976 - accuracy: 0.3685 - auc: 0.5384 - val_loss: 1.0973 - val_accuracy: 0.3782 - val_auc: 0.5213
Epoch 2/10
73/73 [==============================] - 76s 1s/step - loss: 1.0673 - accuracy: 0.4324 - auc: 0.6177 - val_loss: 1.0331 - val_accuracy: 0.5462 - val_auc: 0.7045
Epoch 3/10
73/73 [==============================] - 76s 1s/step - loss: 1.0425 - accuracy: 0.4698 - auc: 0.6460 - val_loss: 1.0557 - val_accuracy: 0.4874 - val_auc: 0.6291
Epoch 4/10
73/73 [==============================] - 76s 1s/step - loss: 1.0220 - accuracy: 0.4809 - auc: 0.6680 - val_loss: 1.0440 - val_accuracy: 0.4748 - val_auc: 0.6358
Epoch 5/10
73/73 [==============================] - 76s 1s/step - loss: 1.0033 - accuracy: 0.4818 - auc: 0.6844 - val_loss: 0.9900 - val_accuracy: 0.5294 - val_auc: 0.7029
Epoch 6/10
73/73 [==============================] - 76s 1s/step - loss: 0.9781 - accuracy: 0.5204 - auc: 0.7089 - val_loss: 0.9063 - val_accuracy: 0.6050 - val_auc: 0.7788
Epoch 7/10
73/73 [==============================] - 76s 1s/step - loss: 0.9582 - accuracy: 0.5311 - auc: 0.7201 - val_loss: 0.9941 - val_accuracy: 0.5252 - val_auc: 0.7040
Epoch 8/10
73/73 [==============================] - 76s 1s/step - loss: 0.9475 - accuracy: 0.5354 - auc: 0.7304 - val_loss: 1.0089 - val_accuracy: 0.5168 - val_auc: 0.6837
Epoch 9/10
73/73 [==============================] - 76s 1s/step - loss: 0.9284 - accuracy: 0.5504 - auc: 0.7456 - val_loss: 1.0140 - val_accuracy: 0.5084 - val_auc: 0.6811
Epoch 10/10
73/73 [==============================] - 75s 1s/step - loss: 0.9063 - accuracy: 0.5689 - auc: 0.7583 - val_loss: 0.9745 - val_accuracy: 0.5336 - val_auc: 0.7159


---------------------------------------------------------------------------
FileNotFoundError                         Traceback (most recent call last)
<ipython-input-20-d4b2257dc3e6> in <module>()
      4
      5 rnn_cnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_cnn.hdf5")
----> 6 with open('Data/trainHistory/rnn_cnn.pkl', 'wb') as file_pi:
      7     pickle.dump(model_dict["rnn_cnn"].history, file_pi)

FileNotFoundError: [Errno 2] No such file or directory: 'Data/trainHistory/rnn_cnn.pkl'
```

5. Model Evaluation

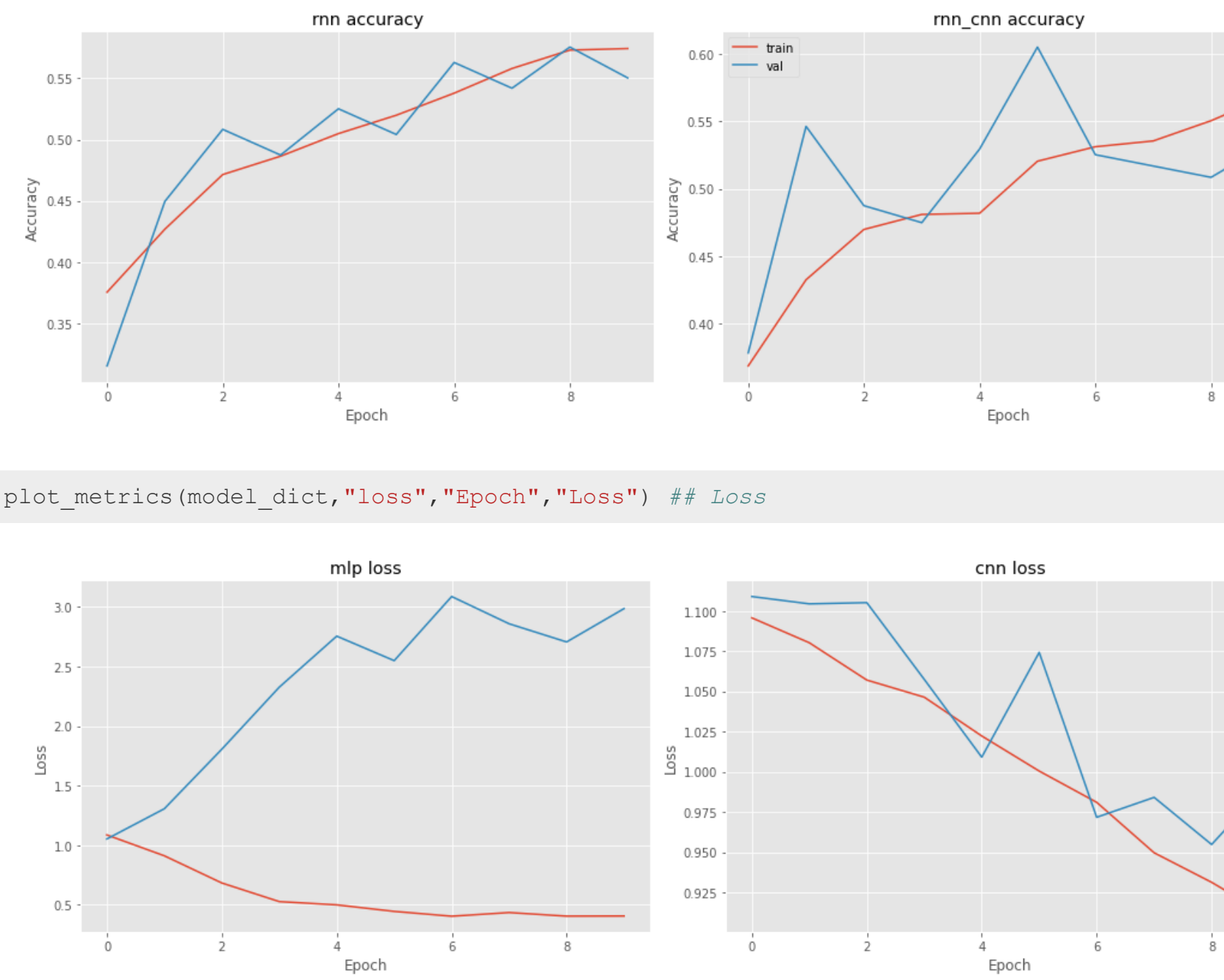
Loss, Accuracy, and AUC_ROC graphs for training and validation data

```python
X_test = pd.read_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/X_test.pkl")
y_test = pd.read_pickle("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/y_test.pkl")
docs_test = np.load("/content/drive/My Drive/NLP-Stock-Prediction-master/Pickles/docs_test.npy")

mlp_hist = pickle.load(open("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/mlp.pkl","rb"))
cnn_hist = pickle.load(open("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/cnn.pkl","rb"))
rnn_hist = pickle.load(open("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn.pkl","rb"))
rnn_cnn_hist = pickle.load(open("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn_cnn.pkl","rb"))
```

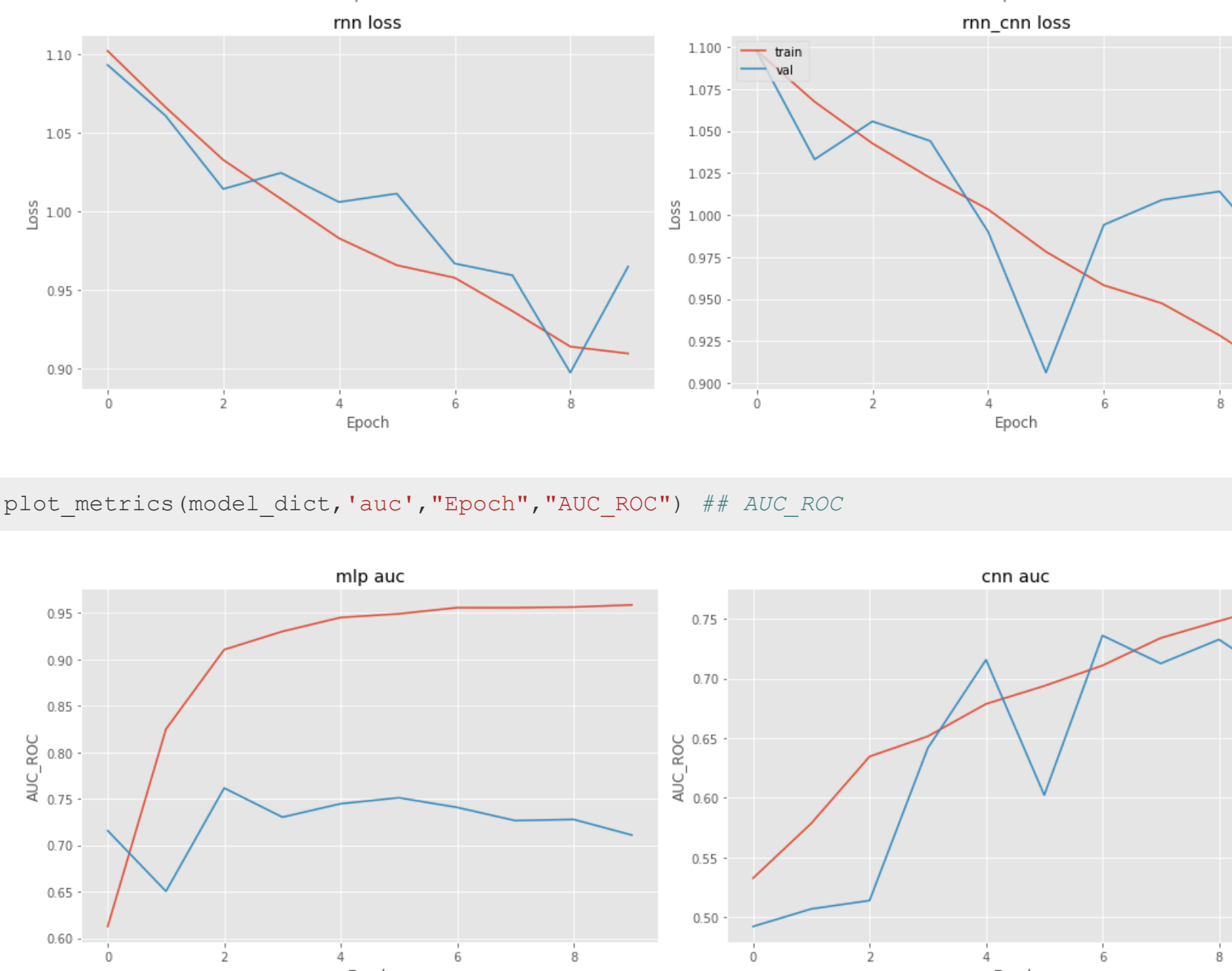
```python
from keras.models import load_model

mlp = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/mlp.hdf5')
cnn = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/cnn.hdf5')
rnn = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn.hdf5')
rnn_cnn = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_cnn.hdf5')
```

```python
def plot_metrics(model_dict, metric, x_label, y_label):
    val_metric = 'val_'+metric
    plots = 1
    plt.figure(figsize=[15,10])
    for model, history in model_dict.items():
        plt.subplot(2, 2, plots)
        plt.plot(history[metric])
        plt.plot(history[val_metric])
        plt.title('{0} {1}'.format(model, metric))
        plt.ylabel(y_label)
        plt.xlabel(x_label)
        plots += 1
    plt.legend(['train', 'val'], loc='upper left')
    plt.tight_layout()
    #plt.savefig("Graphs/{}.png".format(metric),format="png") uncomment later
    plt.show()
plt.style.use("ggplot")
model_dict = {"mlp": mlp_hist,
              "cnn": cnn_hist,
              "rnn": rnn_hist,
              "rnn_cnn": rnn_cnn_hist}
```

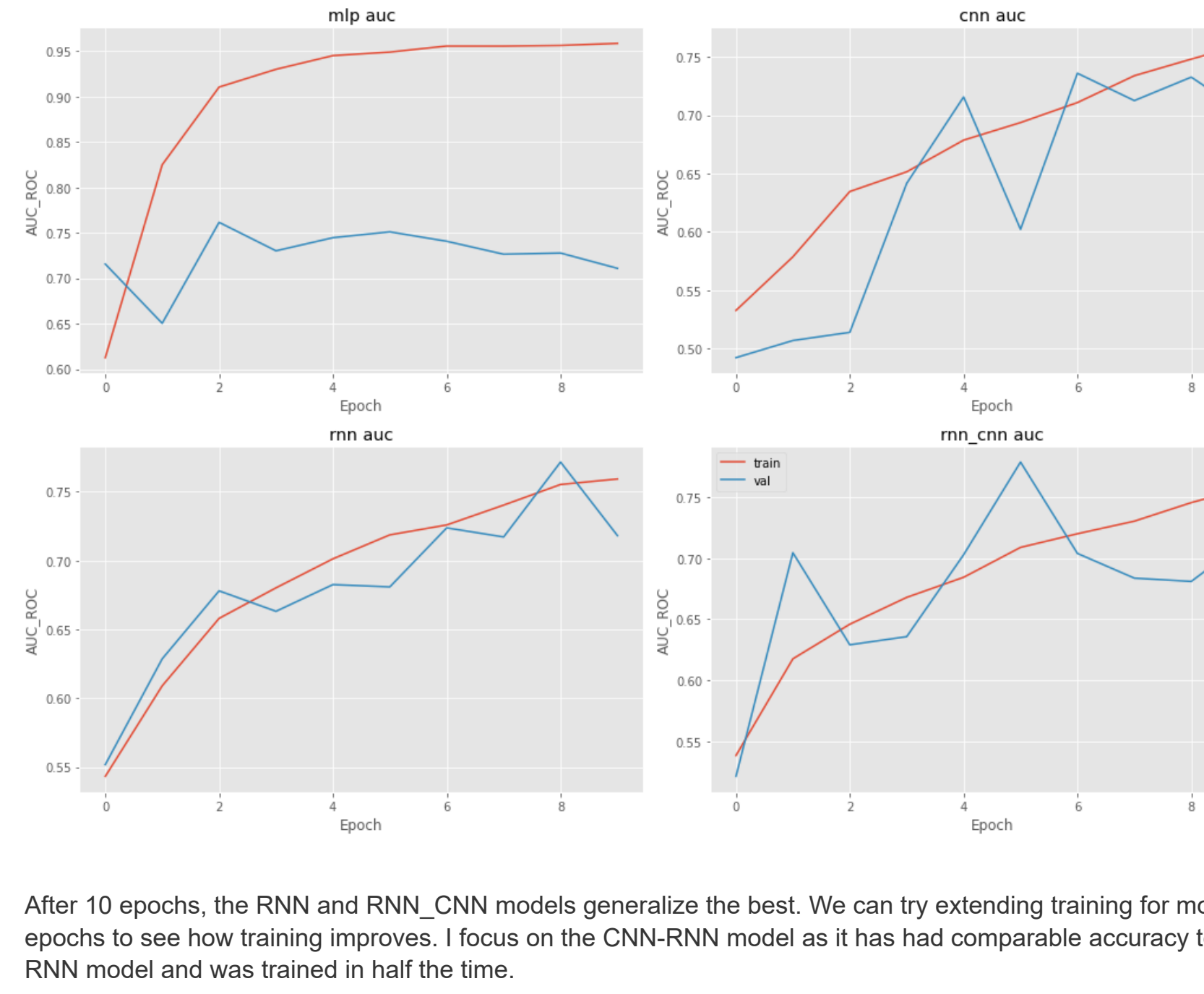
```python
plot_metrics(model_dict,"accuracy", "Epoch", "Accuracy") ## Accuracy
```




```python
plot_metrics(model_dict,"loss","Epoch","Loss") ## Loss
```




```python
plot_metrics(model_dict,'auc',"Epoch","AUC_ROC") ## AUC_ROC
```



After 10 epochs, the RNN and RNN_CNN models generalize the best. We can try extending training for more epochs to see how training improves. I focus on the CNN-RNN model as it has had comparable accuracy to the RNN model and was trained in half the time.

6. Extend Training for More Epochs

```
In [ ]: history = rnn_cnn.fit(x = [docs_train, X_train],
                              y = y_train,
                              batch_size = 32,
                              epochs = 20,
                              verbose = 1,
                              validation_data = ([docs_val, X_val], y_val))
```

```
Epoch 1/20
73/73 [==============================] - 80s 1s/step - loss: 0.9091 - accuracy: 0.5753 - auc_3: 0.7580 - val_loss: 0.9607 - val_accuracy: 0.5378 - val_auc_3: 0.7278
Epoch 2/20
73/73 [==============================] - 78s 1s/step - loss: 0.8835 - accuracy: 0.5813 - auc_3: 0.7745 - val_loss: 0.9548 - val_accuracy: 0.5420 - val_auc_3: 0.7354
Epoch 3/20
73/73 [==============================] - 77s 1s/step - loss: 0.8616 - accuracy: 0.5997 - auc_3: 0.7860 - val_loss: 1.0498 - val_accuracy: 0.4874 - val_auc_3: 0.6788
Epoch 4/20
73/73 [==============================] - 76s 1s/step - loss: 0.8618 - accuracy: 0.5860 - auc_3: 0.7861 - val_loss: 1.0309 - val_accuracy: 0.5588 - val_auc_3: 0.7166
Epoch 5/20
73/73 [==============================] - 75s 1s/step - loss: 0.8371 - accuracy: 0.6040 - auc_3: 0.7999 - val_loss: 1.2365 - val_accuracy: 0.4412 - val_auc_3: 0.5879
Epoch 6/20
73/73 [==============================] - 75s 1s/step - loss: 0.8169 - accuracy: 0.6233 - auc_3: 0.8118 - val_loss: 1.0575 - val_accuracy: 0.5336 - val_auc_3: 0.7142
Epoch 7/20
73/73 [==============================] - 75s 1s/step - loss: 0.8217 - accuracy: 0.6212 - auc_3: 0.8096 - val_loss: 1.2524 - val_accuracy: 0.4328 - val_auc_3: 0.5812
Epoch 8/20
73/73 [==============================] - 75s 1s/step - loss: 0.8078 - accuracy: 0.6315 - auc_3: 0.8190 - val_loss: 1.0039 - val_accuracy: 0.5924 - val_auc_3: 0.7480
Epoch 9/20
73/73 [==============================] - 75s 1s/step - loss: 0.7934 - accuracy: 0.6371 - auc_3: 0.8223 - val_loss: 0.9936 - val_accuracy: 0.5504 - val_auc_3: 0.7305
Epoch 10/20
73/73 [==============================] - 74s 1s/step - loss: 0.7724 - accuracy: 0.6478 - auc_3: 0.8335 - val_loss: 1.1169 - val_accuracy: 0.4832 - val_auc_3: 0.6577
Epoch 11/20
73/73 [==============================] - 75s 1s/step - loss: 0.7660 - accuracy: 0.6521 - auc_3: 0.8374 - val_loss: 0.9062 - val_accuracy: 0.6092 - val_auc_3: 0.7841
Epoch 12/20
73/73 [==============================] - 75s 1s/step - loss: 0.7615 - accuracy: 0.6585 - auc_3: 0.8391 - val_loss: 1.0078 - val_accuracy: 0.5504 - val_auc_3: 0.7352
Epoch 13/20
73/73 [==============================] - 74s 1s/step - loss: 0.7372 - accuracy: 0.6692 - auc_3: 0.8492 - val_loss: 1.0354 - val_accuracy: 0.5672 - val_auc_3: 0.7237
Epoch 14/20
73/73 [==============================] - 74s 1s/step - loss: 0.7263 - accuracy: 0.6757 - auc_3: 0.8540 - val_loss: 1.0104 - val_accuracy: 0.5924 - val_auc_3: 0.7522
Epoch 15/20
73/73 [==============================] - 75s 1s/step - loss: 0.7303 - accuracy: 0.6752 - auc_3: 0.8539 - val_loss: 1.0405 - val_accuracy: 0.5378 - val_auc_3: 0.7261
Epoch 16/20
73/73 [==============================] - 75s 1s/step - loss: 0.7179 - accuracy: 0.6744 - auc_3: 0.8571 - val_loss: 1.0532 - val_accuracy: 0.5630 - val_auc_3: 0.7191
Epoch 17/20
73/73 [==============================] - 75s 1s/step - loss: 0.7065 - accuracy: 0.6877 - auc_3: 0.8622 - val_loss: 1.1069 - val_accuracy: 0.5000 - val_auc_3: 0.6974
Epoch 18/20
73/73 [==============================] - 75s 1s/step - loss: 0.7076 - accuracy: 0.6911 - auc_3: 0.8624 - val_loss: 1.0633 - val_accuracy: 0.5462 - val_auc_3: 0.7195
Epoch 19/20
73/73 [==============================] - 75s 1s/step - loss: 0.6818 - accuracy: 0.6928 - auc_3: 0.8729 - val_loss: 1.0602 - val_accuracy: 0.5546 - val_auc_3: 0.7316
Epoch 20/20
73/73 [==============================] - 75s 1s/step - loss: 0.6681 - accuracy: 0.7117 - auc_3: 0.8790 - val_loss: 1.0595 - val_accuracy: 0.5756 - val_auc_3: 0.7352
```

```
In [ ]: rnn_cnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_cnn_30.hdf5")
        with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn_cnn_30.pkl', 'wb') as file_pi:
            pickle.dump(history.history, file_pi)
```

Validation accuracy doesn't seem to be improving much, we can try training for another few epochs to be safe...

```
In [ ]: history2 = rnn.fit(x = [docs_train, X_train],
                           y = y_train,
                           batch_size = 32,
                           epochs = 20,
                           verbose = 1,
                           validation_data = ([docs_val, X_val], y_val))
```

```
Epoch 1/20
73/73 [==============================] - 141s 2s/step - loss: 0.8902 - accuracy: 0.5890 - auc_2: 0.7716 - val_loss: 1.0983 - val_accuracy: 0.4580 - val_auc_2: 0.6252
Epoch 2/20
73/73 [==============================] - 140s 2s/step - loss: 0.8790 - accuracy: 0.5976 - auc_2: 0.7787 - val_loss: 1.1019 - val_accuracy: 0.4118 - val_auc_2: 0.6162
Epoch 3/20
73/73 [==============================] - 140s 2s/step - loss: 0.8543 - accuracy: 0.6152 - auc_2: 0.7946 - val_loss: 0.8735 - val_accuracy: 0.6176 - val_auc_2: 0.7939
Epoch 4/20
73/73 [==============================] - 140s 2s/step - loss: 0.8470 - accuracy: 0.6233 - auc_2: 0.7966 - val_loss: 0.9248 - val_accuracy: 0.5504 - val_auc_2: 0.7490
Epoch 5/20
73/73 [==============================] - 140s 2s/step - loss: 0.8345 - accuracy: 0.6139 - auc_2: 0.8035 - val_loss: 0.9487 - val_accuracy: 0.5420 - val_auc_2: 0.7363
Epoch 6/20
73/73 [==============================] - 140s 2s/step - loss: 0.8364 - accuracy: 0.6105 - auc_2: 0.8013 - val_loss: 1.0460 - val_accuracy: 0.4958 - val_auc_2: 0.6959
Epoch 7/20
73/73 [==============================] - 140s 2s/step - loss: 0.8080 - accuracy: 0.6435 - auc_2: 0.8177 - val_loss: 1.0040 - val_accuracy: 0.5672 - val_auc_2: 0.7187
Epoch 8/20
73/73 [==============================] - 139s 2s/step - loss: 0.7919 - accuracy: 0.6547 - auc_2: 0.8259 - val_loss: 1.1395 - val_accuracy: 0.4496 - val_auc_2: 0.6565
Epoch 9/20
73/73 [==============================] - 140s 2s/step - loss: 0.7784 - accuracy: 0.6534 - auc_2: 0.8312 - val_loss: 1.0340 - val_accuracy: 0.5882 - val_auc_2: 0.7554
Epoch 10/20
73/73 [==============================] - 141s 2s/step - loss: 0.7758 - accuracy: 0.6478 - auc_2: 0.8320 - val_loss: 1.0125 - val_accuracy: 0.5798 - val_auc_2: 0.7425
Epoch 11/20
73/73 [==============================] - 143s 2s/step - loss: 0.7515 - accuracy: 0.6658 - auc_2: 0.8425 - val_loss: 1.0021 - val_accuracy: 0.5798 - val_auc_2: 0.7556
Epoch 12/20
73/73 [==============================] - 146s 2s/step - loss: 0.7427 - accuracy: 0.6615 - auc_2: 0.8468 - val_loss: 0.9929 - val_accuracy: 0.6303 - val_auc_2: 0.7767
Epoch 13/20
73/73 [==============================] - 145s 2s/step - loss: 0.7174 - accuracy: 0.6834 - auc_2: 0.8581 - val_loss: 1.1007 - val_accuracy: 0.5546 - val_auc_2: 0.7121
Epoch 14/20
73/73 [==============================] - 146s 2s/step - loss: 0.7176 - accuracy: 0.6782 - auc_2: 0.8575 - val_loss: 1.1189 - val_accuracy: 0.5126 - val_auc_2: 0.7078
Epoch 15/20
73/73 [==============================] - 145s 2s/step - loss: 0.7008 - accuracy: 0.6933 - auc_2: 0.8646 - val_loss: 1.1064 - val_accuracy: 0.4832 - val_auc_2: 0.6613
Epoch 16/20
73/73 [==============================] - 144s 2s/step - loss: 0.7060 - accuracy: 0.6817 - auc_2: 0.8620 - val_loss: 1.1454 - val_accuracy: 0.4916 - val_auc_2: 0.6662
Epoch 17/20
73/73 [==============================] - 145s 2s/step - loss: 0.6931 - accuracy: 0.6881 - auc_2: 0.8678 - val_loss: 1.1195 - val_accuracy: 0.5294 - val_auc_2: 0.7161
Epoch 18/20
73/73 [==============================] - 145s 2s/step - loss: 0.6705 - accuracy: 0.7134 - auc_2: 0.8780 - val_loss: 1.1687 - val_accuracy: 0.5462 - val_auc_2: 0.7099
Epoch 19/20
73/73 [==============================] - 143s 2s/step - loss: 0.6780 - accuracy: 0.7057 - auc_2: 0.8738 - val_loss: 1.2671 - val_accuracy: 0.5000 - val_auc_2: 0.6939
Epoch 20/20
73/73 [==============================] - 144s 2s/step - loss: 0.6561 - accuracy: 0.7199 - auc_2: 0.8839 - val_loss: 1.0823 - val_accuracy: 0.6639 - val_auc_2: 0.8055
```

```
In [ ]: rnn.save("/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_30.hdf5")
        with open('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/trainHistory/rnn_30.pkl', 'wb') as file_pi:
            pickle.dump(history2.history, file_pi)
```

It doesn't look more epochs will improve the model any further

5. Evaluation on Test Data

The three metrics are listed as

[test_loss, test_accuracy, test_auc_roc]

```
In [ ]: rnn_cnn_30 = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_cnn_30.hdf5')
        rnn_cnn_30.evaluate([docs_test, X_test], y_test, batch_size=64)
```

```
4/4 [==============================] - 2s 471ms/step - loss: 1.0764 - accuracy: 0.5314 - auc_3: 0.7226

[1.07644522190094, 0.5313807725906372, 0.722558319568634]
```

```
In [ ]: rnn_30 = load_model('/content/drive/My Drive/NLP-Stock-Prediction-master/Data 2/models/rnn_30.hdf5')
        rnn_30.evaluate([docs_test, X_test], y_test, batch_size=64)
```

```
4/4 [==============================] - 3s 871ms/step - loss: 0.9437 - accuracy: 0.6485 - auc_2: 0.8232

[0.94370037317276, 0.6485355496406555, 0.8232173919677734]
```

```
In [ ]: predictions = rnn_30.predict([docs_test, X_test])
        pred_class = predictions.argmax(axis=-1)

        res = (X_test.reset_index()).merge(pd.DataFrame(pred_class.ravel()), left_index = True, right_index=True).rename(columns={0:'Prediction'})
        res2 = df.merge(res, left_on='Unnamed: 0', right_on='index')
        res2[['ticker','signal','Prediction']]
```

	ticker	signal	Prediction
0	ADSK	stay	1
1	ADSK	stay	1
2	ADSK	stay	1
3	ADSK	stay	1
4	ADSK	up	1
...	...	...	...
234	YUM	stay	1
235	YUM	stay	1
236	YUM	stay	0
237	ZBH	up	0
238	ZBH	stay	0

239 rows × 3 columns