LSTM MULTIVARIATE TIME SERIES Baseline Model

Chapter 4.1.1

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

```
Mounted at /content/gdrive
```

```
# Import librries
import pandas as pd
from pandas import DataFrame
from pandas import concat
from sklearn.preprocessing import LabelEncoder
from sklearn.preprocessing import MinMaxScaler
import glob #for maps
import plotly.graph_objects as go
import plotly.offline
import matplotlib.pyplot as plt
from datetime import datetime
import warnings
import itertools
import numpy as np
from statsmodels.tsa.stattools import adfuller
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_erro
from math import sqrt
warnings.filterwarnings("ignore")
import plotly.express as px
import seaborn as sns
import pandas as pd
import plotly.graph_objects as go
import matplotlib.pyplot as plt
%matplotlib inline


from sklearn.model_selection import train_test_split
from tensorflow.keras.layers import Dense, Dropout, LSTM
import keras.models
import tensorflow
from keras.models import Sequential
from tensorflow.keras.layers import LSTM
from tensorflow.keras.layers import Dense
```

Data Reading and Additional Processing

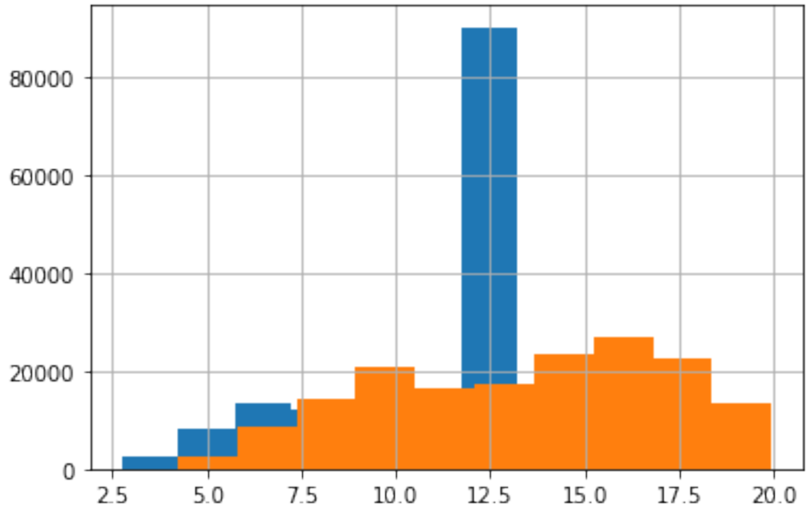
```
fin_data = pd.read_csv('/content/gdrive/MyDrive/Sent/final_data_May20_Sept22
```

```
fin_data.head(5)
```

	latitude	longitute	Year	Month	Day	Hour	nitrogendioxide_tropospheric
0	52.157350	13.716069	2020.0	5.0	1.0	11.0	1.45
1	52.192528	13.806399	2020.0	5.0	1.0	11.0	-6.22
2	52.227226	13.895948	2020.0	5.0	1.0	11.0	5.75
3	52.167213	13.589217	2020.0	5.0	1.0	11.0	1.58
4	52.202910	13.680410	2020.0	5.0	1.0	11.0	1.68

```
print(final_data.shape)
print(fin_data['pm25'].hist())
print(fin_data['pm10'].hist())
```

```
(220179, 15)
AxesSubplot(0.125,0.125;0.775x0.755)
AxesSubplot(0.125,0.125;0.775x0.755)
```




```
fin_data.shape
```

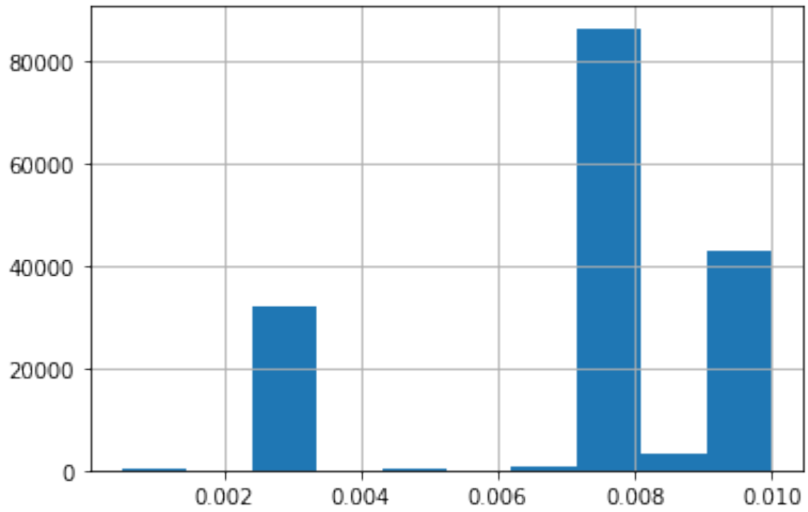
```
(166395, 17)
```

```
fin_data['qa_value'].unique() #quality value
```

```
array([0.0074, 0.01  , 0.0011, 0.0067, 0.009 , 0.0033, 0.0015, 0.0045,
       0.003 , 0.0014, 0.0005, 0.001 , 0.0073])
```

```
fin_data['qa_value'].hist()
```

<matplotlib.axes._subplots.AxesSubplot at 0x7f0742f034f0>




```
fin_data = fin_data.loc[(fin_data['qa_value'] > 0.004)]
```

```
fin_data.shape
```

(133820, 17)

```
fin_data.sort_values(by='date', inplace=True)
fin_data.head()
```

	latitude	longitute	Year	Month	Day	Hour	nitrogendioxide_tropospheri
0	52.157350	13.716069	2020.0	5.0	1.0	11.0	1.4
95	52.548504	13.041852	2020.0	5.0	1.0	11.0	1.2
96	52.585503	13.135360	2020.0	5.0	1.0	11.0	-4.1
97	52.621986	13.228033	2020.0	5.0	1.0	11.0	8.2
98	52.657963	13.319888	2020.0	5.0	1.0	11.0	1.6

```
data_LSTM_test1=fin_data.drop(columns=['date', 'utc', 'pm25','tm5_tropopause_
```

```
data_LSTM_test1.head(5)
```

	nitrogendioxide_tropospheric_column	nitrogendioxide_tropospheric_colum
0	1.459978e-05	
95	1.250596e-05	
96	-4.180619e-07	
97	8.273078e-06	
98	1.682993e-05	

Feature Engineering for LSTM

Referenece:

The model scrip was adopted from the following webpage:

https://machinelearningmastery.com/multivariate-time-series-forecasting-lstms-keras/

https://machinelearningmastery.com/time-series-prediction-lstm-recurrent-neural-networks-python-keras/

```

# convert series to supervised learning
def series_to_supervised(data, n_in=1, n_out=1, dropnan=True):
    n_vars = 1 if type(data) is list else data.shape[1]
    df = DataFrame(data)
    cols, names = list(), list()
    # input sequence (t-n, ... t-1)
    for i in range(n_in, 0, -1):
        cols.append(df.shift(i))
        names += [('var%d(t-%d)' % (j+1, i)) for j in range(n_vars)]
    # forecast sequence (t, t+1, ... t+n)
    for i in range(0, n_out):
        cols.append(df.shift(-i))
        if i == 0:
            names += [('var%d(t)' % (j+1)) for j in range(n_vars)]
        else:
            names += [('var%d(t+%d)' % (j+1, i)) for j in range(n_vars)]
    # put it all together
    agg = concat(cols, axis=1)
    agg.columns = names
    # drop rows with NaN values
    if dropnan:
        agg.dropna(inplace=True)
    return agg

# load dataset
values = data_LSTM_test1.values
# integer encode direction
encoder = LabelEncoder()
#values[:,8] = encoder.fit_transform(values[:,8])
values
# ensure all data is float
values = values.astype('float32')
# normalize features
scaler = MinMaxScaler(feature_range=(0, 1))
scaled = scaler.fit_transform(values)
# frame as supervised learning
reframed = series_to_supervised(scaled, 1, 1)
reframed.drop(reframed.columns[[0,6, 8,9,10,11]], axis=1, inplace=True)
print(reframed.head())
```

```
   var2(t-1)  var3(t-1)  var4(t-1)  var5(t-1)  var6(t-1)   var2(t)
1   0.018191   0.018763   0.243149   0.357339   0.129479  0.008212
2   0.008212   0.008622   0.266456   0.371345   0.129479  0.008405
3   0.008405   0.009252   0.232822   0.350280   0.129479  0.009880
4   0.009880   0.010570   0.258888   0.361394   0.129479  0.012215
5   0.012215   0.012459   0.232868   0.347342   0.129479  0.009161
```

```
#Train/Val/Test
values = reframed.values
x, x_test, y, y_test = train_test_split(values[:, :-1],values[:,-1],test_size
x_train, x_val, train_y, val_y = train_test_split(x,y,test_size = 0.2,train_s
```

```
# reshape input to be 3D [samples, timesteps, features]
train_X = x_train.reshape((x_train.shape[0], 1, x_train.shape[1]))
val_X = x_val.reshape((x_val.shape[0], 1, x_val.shape[1]))
test_X = x_test.reshape((x_test.shape[0], 1, x_test.shape[1]))
```

```
print(train_X.shape, train_y.shape, val_X.shape, val_y.shape, test_X.shape, y
```

```
(96349, 1, 5) (96349,) (24088, 1, 5) (24088,) (13382, 1, 5) (13382,)
```

LSTM Baseline

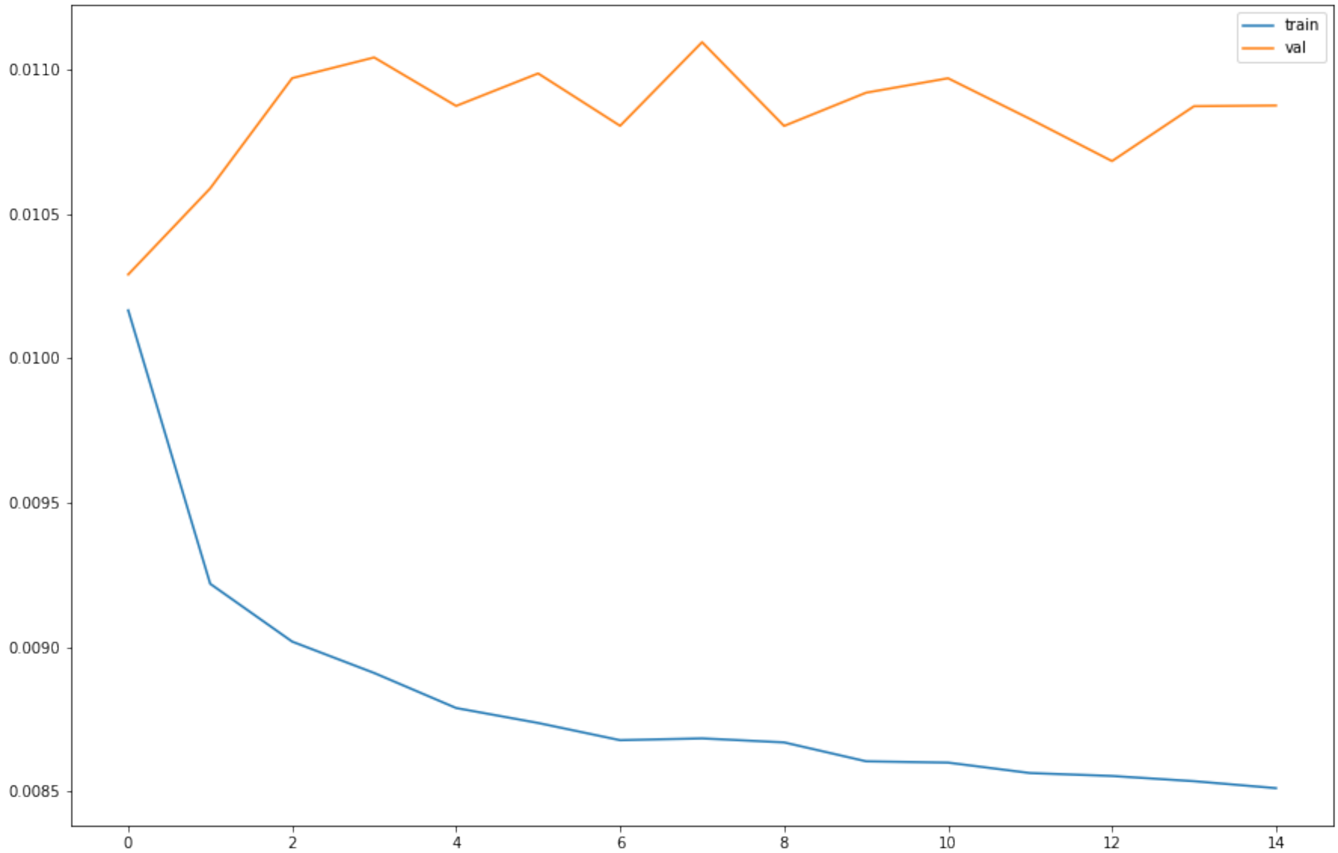
```
%%time
model = Sequential()
model.add(LSTM(500, input_shape=(train_X.shape[1], train_X.shape[2])))
model.add(Dropout(0.2))
model.add(Dense(1))
model.compile(loss='mae', optimizer='adam') #mean absolute error
history = model.fit(train_X, train_y, epochs=15, batch_size=64, validation_da

#plot history
plt.figure(figsize=(15, 10))

pyplot.plot(history.history['loss'], label='train')
pyplot.plot(history.history['val_loss'], label='val')
pyplot.legend()
pyplot.show()
```

```
Epoch 1/15
1506/1506 - 39s - loss: 0.0102 - val_loss: 0.0103 - 39s/epoch - 26ms/step
Epoch 2/15
1506/1506 - 29s - loss: 0.0092 - val_loss: 0.0106 - 29s/epoch - 19ms/step
Epoch 3/15
1506/1506 - 29s - loss: 0.0090 - val_loss: 0.0110 - 29s/epoch - 19ms/step
Epoch 4/15
1506/1506 - 29s - loss: 0.0089 - val_loss: 0.0110 - 29s/epoch - 19ms/step
Epoch 5/15
1506/1506 - 29s - loss: 0.0088 - val_loss: 0.0109 - 29s/epoch - 19ms/step
Epoch 6/15
1506/1506 - 28s - loss: 0.0087 - val_loss: 0.0110 - 28s/epoch - 18ms/step
Epoch 7/15
```

```
1506/1506 - 28s - loss: 0.0087 - val_loss: 0.0108 - 28s/epoch - 18ms/step
Epoch 8/15
1506/1506 - 28s - loss: 0.0087 - val_loss: 0.0111 - 28s/epoch - 19ms/step
Epoch 9/15
1506/1506 - 28s - loss: 0.0087 - val_loss: 0.0108 - 28s/epoch - 18ms/step
Epoch 10/15
1506/1506 - 28s - loss: 0.0086 - val_loss: 0.0109 - 28s/epoch - 18ms/step
Epoch 11/15
1506/1506 - 31s - loss: 0.0086 - val_loss: 0.0110 - 31s/epoch - 21ms/step
Epoch 12/15
1506/1506 - 28s - loss: 0.0086 - val_loss: 0.0108 - 28s/epoch - 19ms/step
Epoch 13/15
1506/1506 - 28s - loss: 0.0086 - val_loss: 0.0107 - 28s/epoch - 19ms/step
Epoch 14/15
1506/1506 - 28s - loss: 0.0085 - val_loss: 0.0109 - 28s/epoch - 19ms/step
Epoch 15/15
1506/1506 - 29s - loss: 0.0085 - val_loss: 0.0109 - 29s/epoch - 19ms/step
```



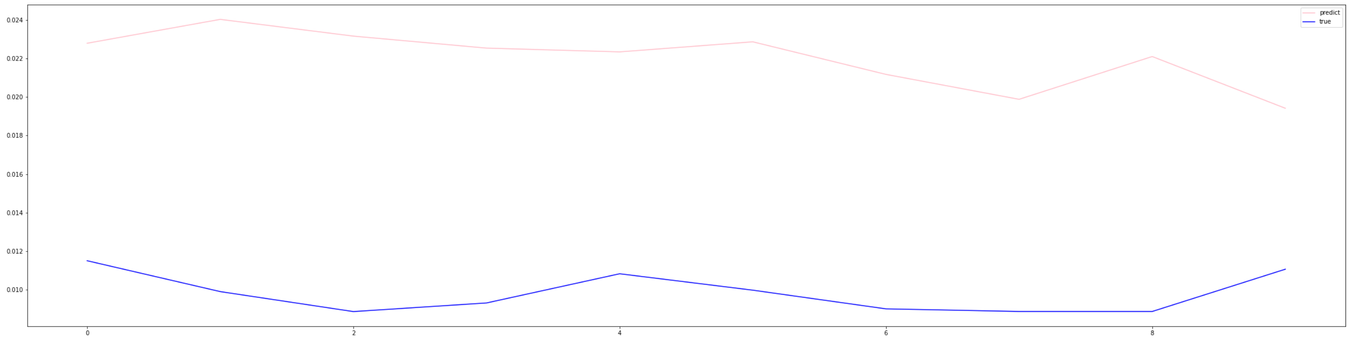

```
CPU times: user 11min 55s, sys: 27.3 s, total: 12min 22s
Wall time: 7min 18s
```

```
#Validation set (8 days forecast)

yhat = model.predict(val_X)
plt.figure(figsize=(40, 10))
pyplot.plot(yhat[-10:], label='predict', color = 'pink')
pyplot.plot(val_y[-10:], label='true', color = 'blue')
pyplot.legend()

pyplot.show()
```

```
753/753 [==============================] - 4s 5ms/step
```

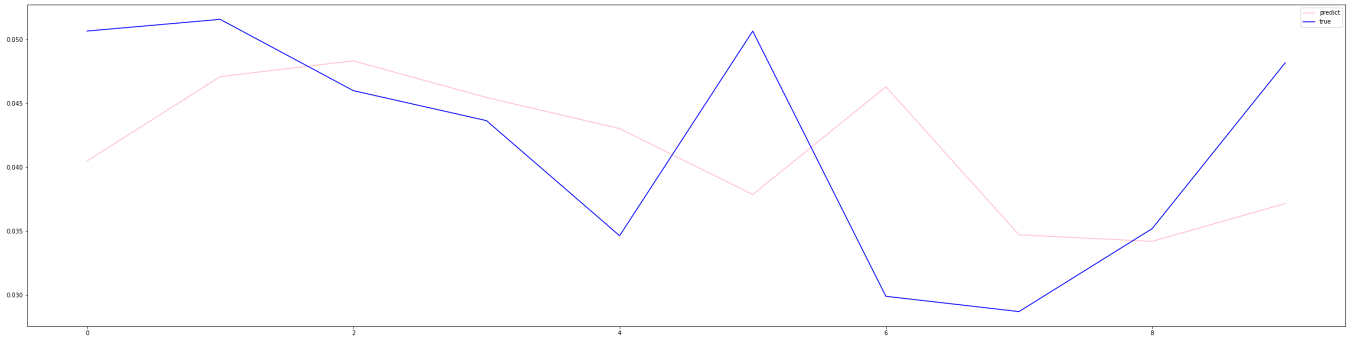


```
#Train set (8 days forecast)

yhat = model.predict(train_X)
plt.figure(figsize=(40, 10))
pyplot.plot(yhat[-10:], label='predict', color = 'pink')
pyplot.plot(train_y[-10:], label='true', color = 'blue')
pyplot.legend()

pyplot.show()
```

```
3011/3011 [==============================] - 15s 5ms/step
```



```
#Test set (8 days forecast)

yhat = model.predict(test_X)
plt.figure(figsize=(40, 10))
pyplot.plot(yhat[-10:], label='predict', color = 'pink')
pyplot.plot(y_test[-10:], label='true', color = 'blue')
pyplot.legend()

pyplot.show()
```

```
419/419 [==============================] - 2s 6ms/step
```