CSC 578 - Class Project, Time Series Kaggle

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GPU Check

Since we are using Google Colab, this will check if GPUs on Google Collab are being used and how many GPUs are being used. If I were using Anaconda, then it would also enable memory growth.

In [ ]:
```
import tensorflow as tf
print("Num GPUs Available: ", len(tf.config.list_physical_devices('GPU')))

# tf.config.experimental.set_memory_growth(physical_devices[0], True)
```

```
Num GPUs Available:  1
```

Import Libraries

In [ ]:
```
import os
import datetime

import IPython
import IPython.display
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
import tensorflow as tf
```

Data Set Import

Read file into Collab and retrieve its location via file path.

In [ ]:
```
csv_path = tf.keras.utils.get_file(
 origin='https://reed.cs.depaul.edu/peterh/Essays/Metro_Interstate_reduced.csv',
 fname='Metro_Interstate_reduced.csv',
 cache_dir='/content', cache_subdir='sample_data')

csv_path
```

```
Downloading data from https://reed.cs.depaul.edu/peterh/Essays/Metro_Interstate_reduced.cs
v
2711552/2703553 [==============================] - 0s 0us/step
2719744/2703553 [==============================] - 0s 0us/step
```

Out[ ]:
```
'/content/sample_data/Metro_Interstate_reduced.csv'
```

Exploratory Data Analysis

In [ ]:
```
df = pd.read_csv(csv_path, header=0)   #, index_col=0
```

View data:

Check that the data has loaded correctly, view data values and data index.

In [ ]:

```
datavalues = df.values
dataindex = df.index
```

View data frame head and data frame tail:

Inspecting and reviewing the data.

In [ ]:

```
df.head()
```

Out[ ]:

	holiday	temp	rain_1h	snow_1h	clouds_all	weather_main	weather_description	date_time	traffic_volume
0	None	288.28	0.0	0.0	40	Clouds	scattered clouds	2012-10-02 09:00:00	5545
1	None	289.36	0.0	0.0	75	Clouds	broken clouds	2012-10-02 10:00:00	4516
2	None	289.58	0.0	0.0	90	Clouds	overcast clouds	2012-10-02 11:00:00	4767
3	None	290.13	0.0	0.0	90	Clouds	overcast clouds	2012-10-02 12:00:00	5026
4	None	291.14	0.0	0.0	75	Clouds	broken clouds	2012-10-02 13:00:00	4918

In [ ]:

```
df.tail()
```

Out[ ]:

	holiday	temp	rain_1h	snow_1h	clouds_all	weather_main	weather_description	date_time	traffic_volume
40570	None	283.45	0.0	0.0	75	Clouds	broken clouds	2018-09-30 19:00:00	3543
40571	None	282.76	0.0	0.0	90	Clouds	overcast clouds	2018-09-30 20:00:00	2781
40572	None	282.73	0.0	0.0	90	Thunderstorm	proximity thunderstorm	2018-09-30 21:00:00	2159
40573	None	282.09	0.0	0.0	90	Clouds	overcast clouds	2018-09-30 22:00:00	1450
40574	None	282.12	0.0	0.0	90	Clouds	overcast clouds	2018-09-30 23:00:00	954

Data statistics:

Descriptive statistics for the numerical fields, view the mean, std, min, max, etc.

In [ ]:

```
df.describe()
```

Out[ ]:

	temp	rain_1h	snow_1h	clouds_all	traffic_volume

	temp	rain_1h	snow_1h	clouds_all	traffic_volume
count	40575.000000	40575.000000	40575.000000	40575.000000	40575.000000
mean	281.316763	0.318632	0.000117	44.199162	3290.650474
std	13.816618	48.812640	0.005676	38.683447	1984.772909
min	0.000000	0.000000	0.000000	0.000000	0.000000
25%	271.840000	0.000000	0.000000	1.000000	1248.500000
50%	282.860000	0.000000	0.000000	40.000000	3427.000000
75%	292.280000	0.000000	0.000000	90.000000	4952.000000
max	310.070000	9831.300000	0.510000	100.000000	7280.000000

Drop categorical fields:
Removing the weather_main and weather_description variables as items such as clouds, sunny and overcast may not be measurables, for now. Removing the holiday variable as there are only a handful of holidays listed in the data.

In [ ]:
```
df = df.drop(['holiday', 'weather_main', 'weather_description'], axis = 1)
```

Data frame index:
The date_time variable will become the data frame index.

In [ ]:
```
df.index = pd.to_datetime(df['date_time'], format='%Y-%m-%d %H:%M:%S')
```

Drop date_time field:
The data_time variable become the index for this data frame.

In [ ]:
```
df = df.drop(['date_time'], axis = 1)
```

Review Data Frame:
Ensure that the date_time field is the index.

In [ ]:
```
df[:5]
```

Out[ ]:

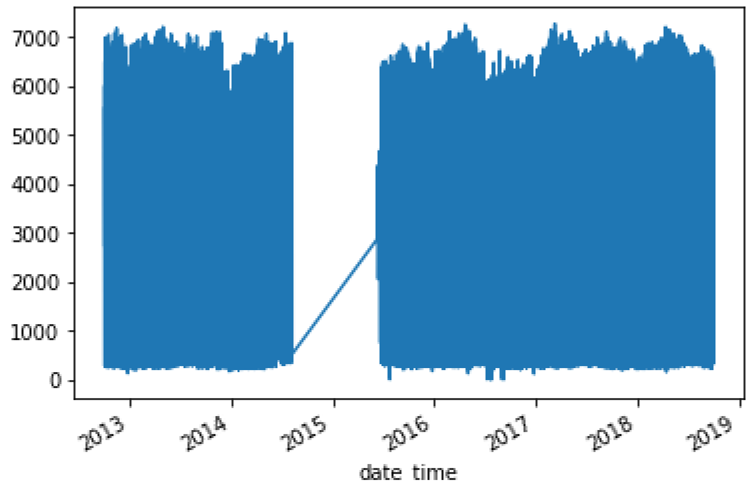
	temp	rain_1h	snow_1h	clouds_all	traffic_volume
date_time					
2012-10-02 09:00:00	288.28	0.0	0.0	40	5545
2012-10-02 10:00:00	289.36	0.0	0.0	75	4516
2012-10-02 11:00:00	289.58	0.0	0.0	90	4767
2012-10-02 12:00:00	290.13	0.0	0.0	90	5026
2012-10-02 13:00:00	291.14	0.0	0.0	75	4918

Plots

Traffic Volume Distribution
This plot should display the distribution of the traffic_volume data, but it doesnt seem to be very helpful.

In [ ]:
```
temp = df['traffic_volume']
temp.plot()
```

Out[ ]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7ff61ceccc90>
```



In [ ]:
```

```

Splitting the Data

Data set is split into 3 sets. The training and validation set are a 70/20 split. The test set is composed of the last 5000 rows from the data frame.

In [ ]:
```
column_indices = {name: i for i, name in enumerate(df.columns)}

n = len(df)

train_df = df[0:int(n*0.7)]
val_df = df[int(n*0.7):int(n*0.9)]
test_df = df[-5000:]

num_features = df.shape[1]
```

In [ ]:
```
#train_df
```

In [ ]:
```
#val_df
```

In [ ]:
```
#test_df
```

Normalize Data

The variables of each data set were normalized.

In [ ]:
```
train_mean = train_df.mean()
train_std = train_df.std()

train_df = (train_df - train_mean) / train_std
```

```
val_df = (val_df - train_mean) / train_std
test_df = (test_df - train_mean) / train_std
```

In [ ]:
```
#train_df
```

In [ ]:
```
#val_df
```

In [ ]:
```
#test_df
```

Window Generator

To

In [ ]:
```
#
# From TF Tutorial
#

class WindowGenerator():
  def __init__(self, input_width, label_width, shift,
               train_df=train_df, val_df=val_df, test_df=test_df,
               label_columns=None):
    # Store the raw data.
    self.train_df = train_df
    self.val_df = val_df
    self.test_df = test_df

    # Work out the label column indices.
    self.label_columns = label_columns
    if label_columns is not None:
      self.label_columns_indices = {name: i for i, name in
                                    enumerate(label_columns)}
    self.column_indices = {name: i for i, name in
                           enumerate(train_df.columns)}

    # Work out the window parameters.
    self.input_width = input_width
    self.label_width = label_width
    self.shift = shift

    self.total_window_size = input_width + shift

    self.input_slice = slice(0, input_width)
    self.input_indices = np.arange(self.total_window_size)[self.input_slice]

    self.label_start = self.total_window_size - self.label_width
    self.labels_slice = slice(self.label_start, None)
    self.label_indices = np.arange(self.total_window_size)[self.labels_slice]

  def __repr__(self):
    return '\n'.join([
        f'Total window size: {self.total_window_size}',
        f'Input indices: {self.input_indices}',
        f'Label indices: {self.label_indices}',
        f'Label column name(s): {self.label_columns}'])
```

In [ ]:
```

```

In [ ]:

```
#
# From TF Tutorial
#

def split_window(self, features):
  inputs = features[:, self.input_slice, :]
  labels = features[:, self.labels_slice, :]
  if self.label_columns is not None:
    labels = tf.stack(
        [labels[:, :, self.column_indices[name]] for name in self.label_columns],
        axis=-1)

  # Slicing doesn't preserve static shape information, so set the shapes
  # manually. This way the `tf.data.Datasets` are easier to inspect.
  inputs.set_shape([None, self.input_width, None])
  labels.set_shape([None, self.label_width, None])

  return inputs, labels

WindowGenerator.split_window = split_window
```

In [ ]:

```
window_5_1_2 = WindowGenerator(input_width=5, label_width=1, shift=2, label_columns=['traf
```

In [ ]:

```
window_5_1_2
```

Out[ ]:

```
Total window size: 7
Input indices: [0 1 2 3 4]
Label indices: [6]
Label column name(s): ['traffic_volume']
```

Plots

In [ ]:

```
#
# From TF Tutorial
#

def plot(self, model=None, plot_col='traffic_volume', max_subplots=3):
  inputs, labels = self.example
  plt.figure(figsize=(12, 8))
  plot_col_index = self.column_indices[plot_col]
  max_n = min(max_subplots, len(inputs))
  for n in range(max_n):
    plt.subplot(max_n, 1, n+1)
    plt.ylabel(f'{plot_col} [normed]')
    plt.plot(self.input_indices, inputs[n, :, plot_col_index],
             label='Inputs', marker='.', zorder=-10)

    if self.label_columns:
      label_col_index = self.label_columns_indices.get(plot_col, None)
    else:
      label_col_index = plot_col_index

    if label_col_index is None:
      continue

    plt.scatter(self.label_indices, labels[n, :, label_col_index],
                edgecolors='k', label='Labels', c='#2ca02c', s=64)
    if model is not None:
      predictions = model(inputs)
      plt.scatter(self.label_indices, predictions[n, :, label_col_index],
                  marker='X', edgecolors='k', label='Predictions',
```

```
                  c='#ff7f0e', s=64)

    if n == 0:
      plt.legend()

  plt.xlabel('date _ time')

WindowGenerator.plot = plot
```

In [ ]:

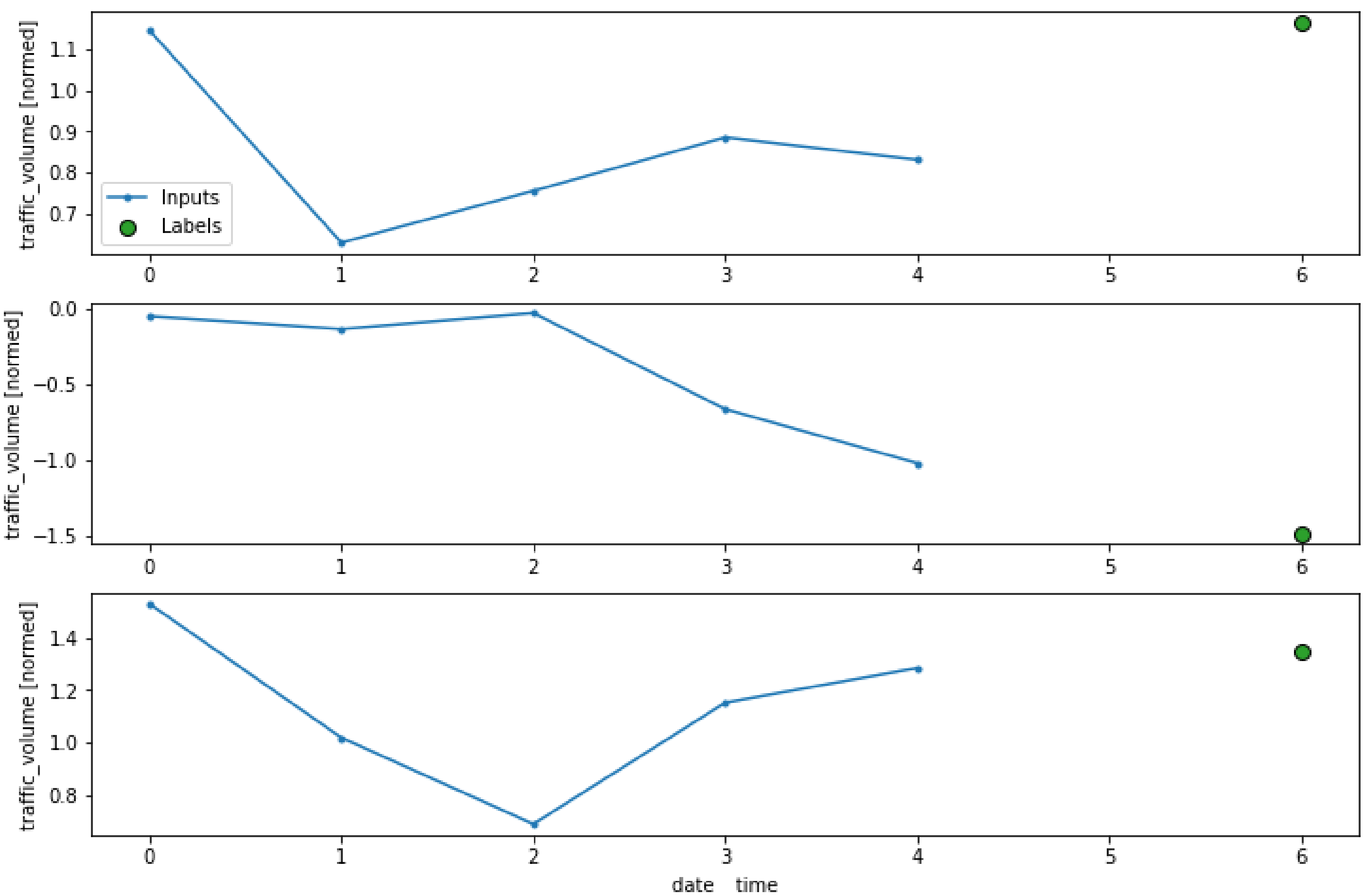
```
#
# From TF Tutorial
#


# Stack three slices, the length of the total window.
first_window = tf.stack([np.array(train_df[:window_5_1_2.total_window_size]),
                           np.array(train_df[100:100+window_5_1_2.total_window_size]),
                           np.array(train_df[200:200+window_5_1_2.total_window_size])])

first_inputs, first_labels = window_5_1_2.split_window(first_window)
```

In [ ]:

```
window_5_1_2.example = first_inputs, first_labels
```

In [ ]:

```
window_5_1_2.plot()
```



Create the Datasets

In [ ]:

```
#
# From TF Tutorial
```

```
#

def make_dataset(self, data):
  data = np.array(data, dtype=np.float32)
  ds = tf.keras.utils.timeseries_dataset_from_array(
      data=data,
      targets=None,
      sequence_length=self.total_window_size,
      sequence_stride=1,
      shuffle=True,
      batch_size=64,)
      #batch_size=32,)

  ds = ds.map(self.split_window)

  return ds

WindowGenerator.make_dataset = make_dataset
```

In [ ]:

```
#
# From TF Tutorial
#

@property
def train(self):
  return self.make_dataset(self.train_df)

@property
def val(self):
  return self.make_dataset(self.val_df)

@property
def test(self):
  return self.make_dataset(self.test_df)

@property
def example(self):
  """Get and cache an example batch of `inputs, labels` for plotting."""
  result = getattr(self, '_example', None)
  if result is None:
    # No example batch was found, so get one from the `.train` dataset
    result = next(iter(self.train))
    # And cache it for next time
    self._example = result
  return result

WindowGenerator.train = train
WindowGenerator.val = val
WindowGenerator.test = test
WindowGenerator.example = example
```

In [ ]:

```
# window_5_1_2.train
# window_5_1_2.val
#window_5_1_2.test
```

Data Models

Baseline Model

Simple baseline model based on the TF tutorial.

In [ ]:

```
single_step = WindowGenerator(
    input_width=1, label_width=1, shift=1,
    label_columns=['traffic_volume'])
single_step
```

Out[ ]:

```
Total window size: 2
Input indices: [0]
Label indices: [1]
Label column name(s): ['traffic_volume']
```

In [ ]:

```
class Baseline(tf.keras.Model):
  def __init__(self, label_index=None):
    super().__init__()
    self.label_index = label_index

  def call(self, inputs):
    if self.label_index is None:
      return inputs
    result = inputs[:, :, self.label_index]
    return result[:, :, tf.newaxis]
```

In [ ]:

```
baseline = Baseline(label_index=column_indices['traffic_volume'])

baseline.compile(loss=tf.losses.MeanSquaredError(),
                 metrics=[tf.metrics.MeanAbsoluteError()])

val_performance = {}
performance = {}
val_performance['Baseline'] = baseline.evaluate(single_step.val)
performance['Baseline'] = baseline.evaluate(single_step.test, verbose=0)
```

```
127/127 [==============================] - 3s 9ms/step - loss: 0.1713 - mean_absolute_erro
r: 0.2973
```

In [ ]:

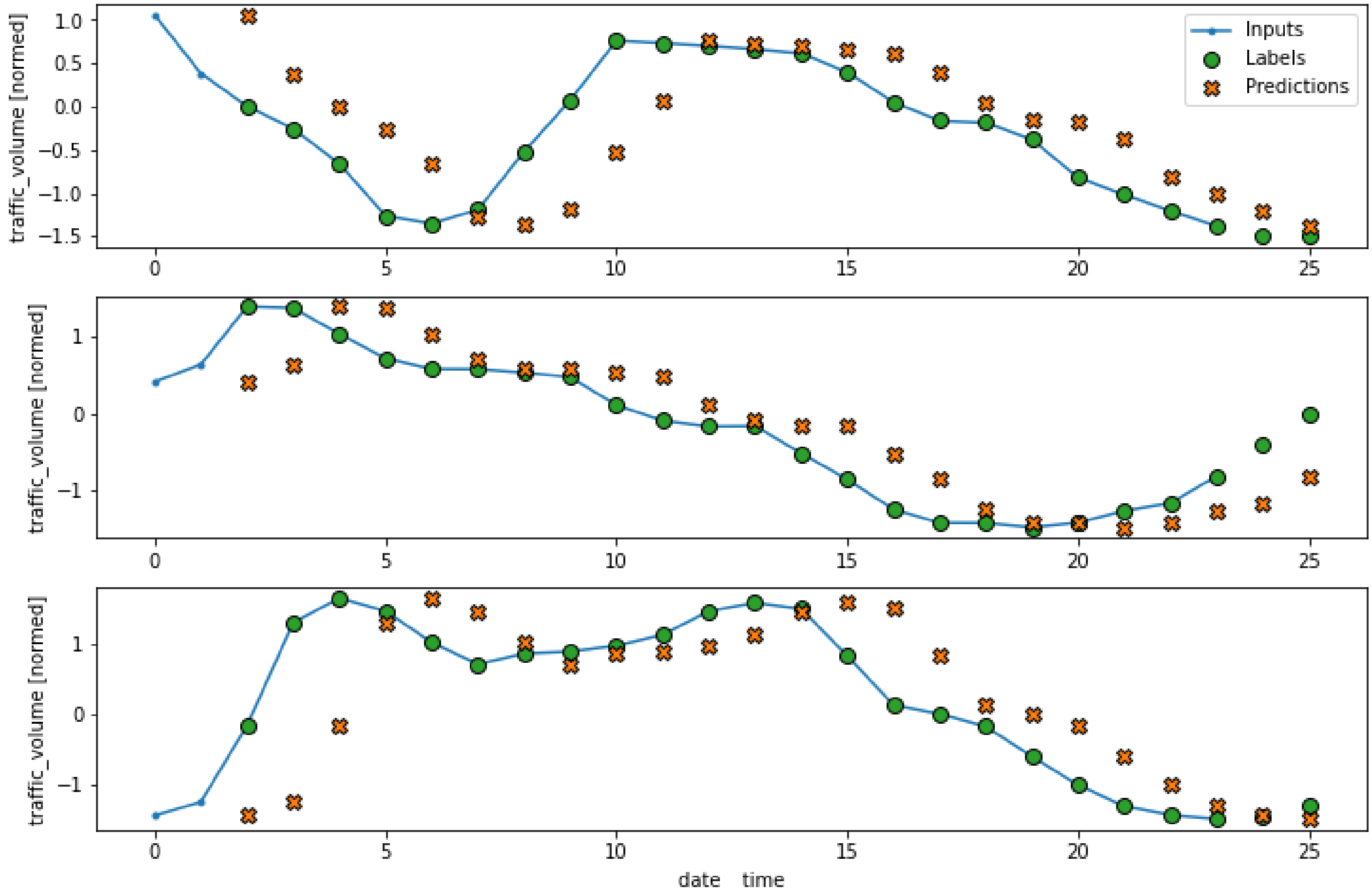
```
wide_window_5_1_2 = WindowGenerator(
    input_width=24, label_width=24, shift=2,
    label_columns=['traffic_volume'])

wide_window_5_1_2
```

Out[ ]:

```
Total window size: 26
Input indices: [ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23]
Label indices: [ 2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25]
Label column name(s): ['traffic_volume']
```

In [ ]:

```
wide_window_5_1_2.plot(baseline)
```



In [ ]:

```
#
# From TF Tutorial
#

MAX_EPOCHS = 30

def compile_and_fit(model, window, patience=2):
  early_stopping = tf.keras.callbacks.EarlyStopping(monitor='val_loss',
                                                    patience=patience,
                                                    mode='min')

  model.compile(loss=tf.losses.MeanSquaredError(),
                optimizer=tf.optimizers.Adam(learning_rate=0.001),
                metrics=[tf.metrics.MeanAbsoluteError()])

  history = model.fit(window.train, epochs=MAX_EPOCHS,
                      validation_data=window.val,
                      callbacks=[early_stopping])
  return history
```

LSTM Model -- Runner-Up

In [ ]:

```
lstm_model = tf.keras.models.Sequential([
    # Shape [batch, time, features] => [batch, time, lstm_units]
    tf.keras.layers.LSTM(128, return_sequences=True),
    #tf.keras.layers.LSTM(240, return_sequences=True),
    #tf.keras.layers.LSTM(240, return_sequences=True),
    #tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Dropout(0.2),
    tf.keras.layers.LSTM(128, return_sequences=True),
    #tf.keras.layers.LSTM(512, return_sequences=True),
    #tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Dropout(0.2),
```

```
    tf.keras.layers.Dense(64, activation='relu'),
    tf.keras.layers.Dense(32, activation='relu'),
    # Shape => [batch, time, features]
    tf.keras.layers.Dense(units=1)
])
```

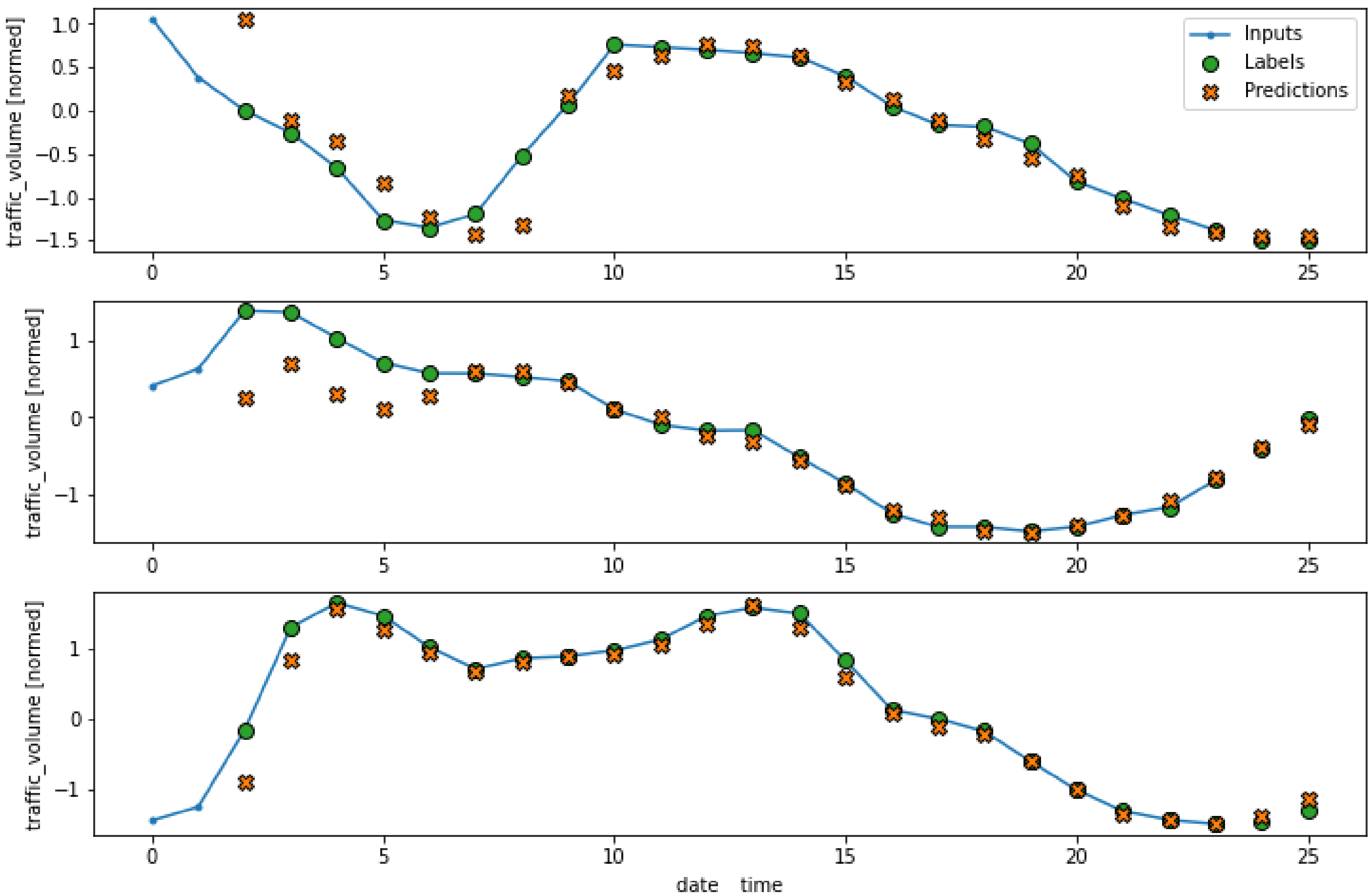
In [ ]:

```
history = compile_and_fit(lstm_model, wide_window_5_1_2)

IPython.display.clear_output()
val_performance['LSTM'] = lstm_model.evaluate(wide_window_5_1_2.val)
performance['LSTM'] = lstm_model.evaluate(wide_window_5_1_2.test, verbose=0)
```

```
127/127 [==============================] - 1s 9ms/step - loss: 0.0629 - mean_absolute_erro
r: 0.1541
```

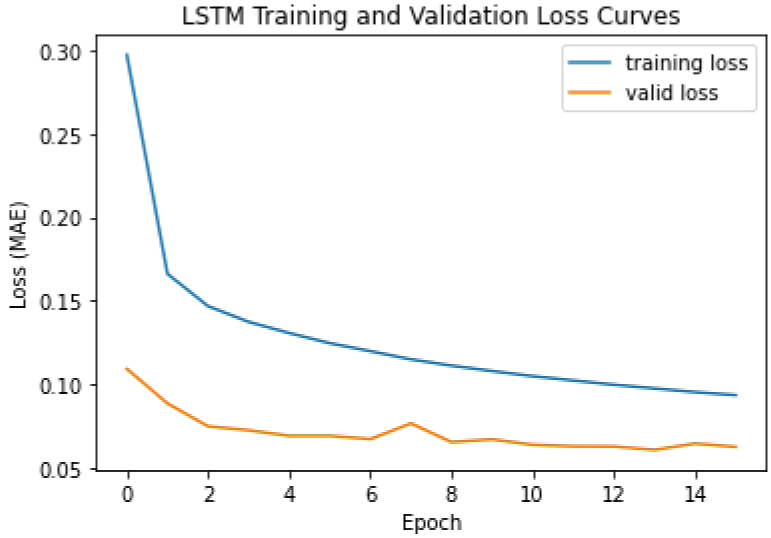
In [ ]:

```
wide_window_5_1_2.plot(lstm_model)
```



In [ ]:

```
plt.plot(history.history['loss'], label='training loss')
plt.plot(history.history['val_loss'], label = 'valid loss')
plt.xlabel('Epoch')
plt.ylabel('Loss (MAE)')
plt.legend(loc='upper right')
plt.title('LSTM Training and Validation Loss Curves')
plt.show()
```



CNN/RNN Model -- Best Model

In [ ]:

```
cnn_rnn_model = tf.keras.models.Sequential([
    tf.keras.layers.Conv1D(256, kernel_size=3, strides=1, padding='same',activation='relu'
    tf.keras.layers.Conv1D(128,  kernel_size=3, padding='same',activation='relu'),
    #tf.keras.layers.Conv1D(64,  kernel_size=3, padding='same',activation='relu'),
    #tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Dropout(0.2),
    tf.keras.layers.LSTM(256, return_sequences=True),
    tf.keras.layers.LSTM(128, return_sequences=True),
    #tf.keras.layers.LSTM(64, return_sequences=True),
    #tf.keras.layers.Dropout(0.1),
    tf.keras.layers.Dense(128, activation='relu'),
    #tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dense(units=1)

])
```

In [ ]:

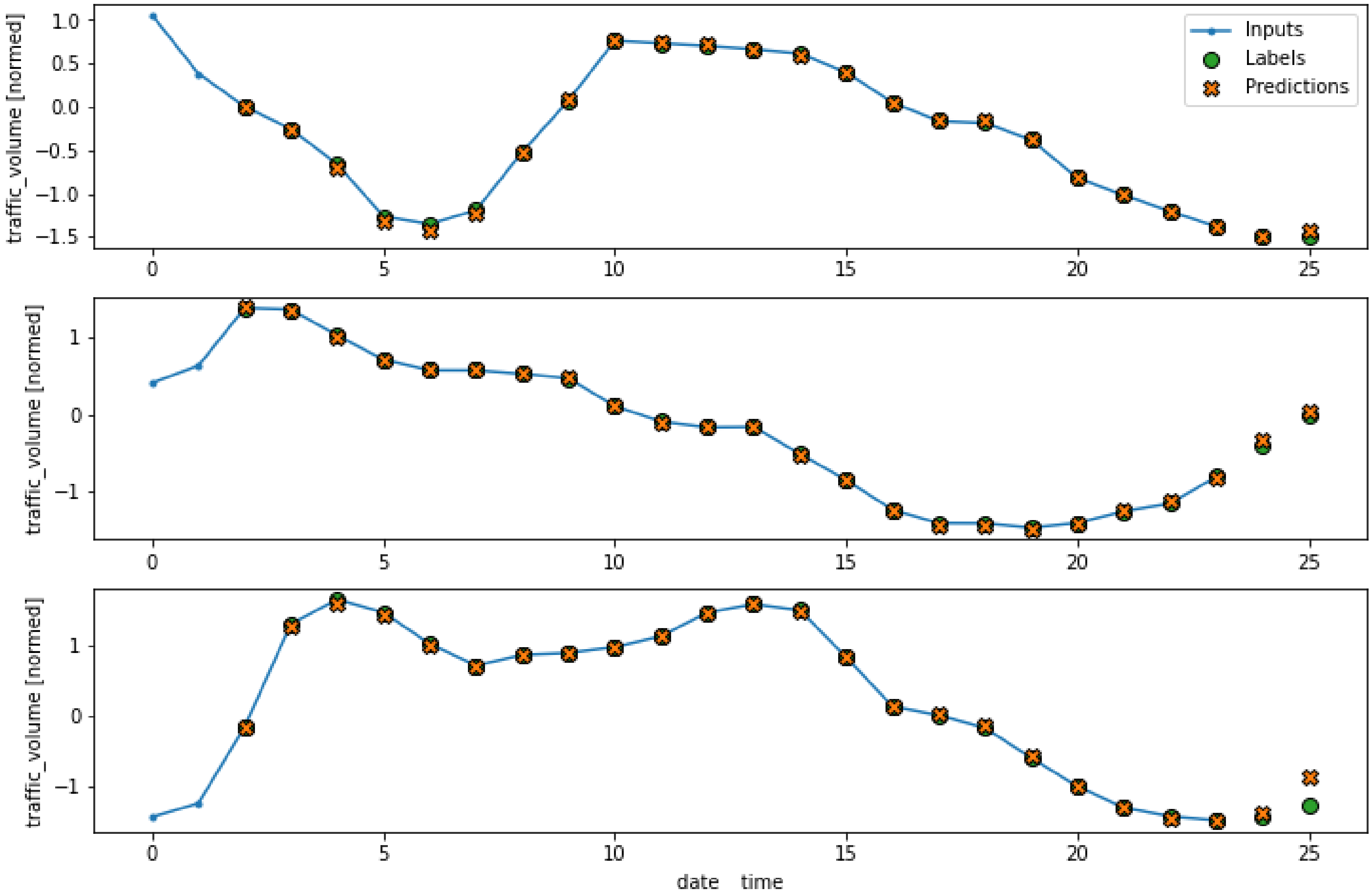
```
history = compile_and_fit(cnn_rnn_model, wide_window_5_1_2)

IPython.display.clear_output()
val_performance['CNN_RNN'] = cnn_rnn_model.evaluate(wide_window_5_1_2.val)
performance['CNN_RNN'] = cnn_rnn_model.evaluate(wide_window_5_1_2.test, verbose=0)
```

```
127/127 [==============================] - 1s 9ms/step - loss: 0.0038 - mean_absolute_erro
r: 0.0319
```

Visual plot for cnn_rnn_model

In [ ]:

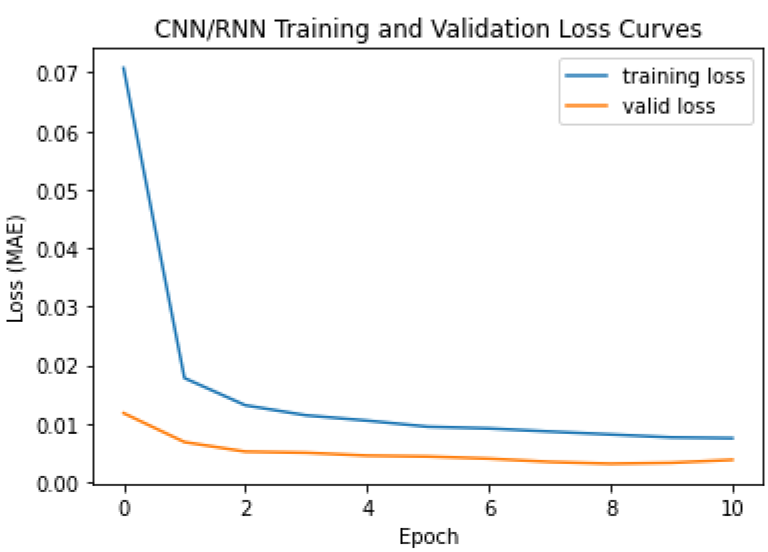
```
wide_window_5_1_2.plot(cnn_rnn_model)
```



CNN_RNN model loss curve

In [ ]:

```
plt.plot(history.history['loss'], label='training loss')
plt.plot(history.history['val_loss'], label = 'valid loss')
plt.xlabel('Epoch')
plt.ylabel('Loss (MAE)')
plt.legend(loc='upper right')
plt.title('CNN/RNN Training and Validation Loss Curves')
plt.show()
```



In [ ]:

```
# x = np.arange(len(val_performance))

# x
```

Predictions

Create predictions based on test set

In [ ]:

```
#prediction = lstm_model.predict(window_5_1_2.test)

prediction = cnn_rnn_model.predict(window_5_1_2.test)
```

In [ ]:

```
len(prediction)
```

Out[ ]:

```
4994
```

In [ ]:

```
prediction.shape, print(type(prediction)), prediction.dtype

#col = pd.DataFrame([prediction], columns=['runs'] )
```

```
<class 'numpy.ndarray'>
```

Out[ ]:

```
((4994, 5, 1), None, dtype('float32'))
```

Put predictions in single array

In [ ]:

```
#prediction[2][4]

i = 0
preds = []
for row in range(0, len(prediction)):
  preds.append(prediction[row][4])

preds

len(preds)
```

Out[ ]:

```
4994
```

Denormalize the predictions

In [ ]:

```
#denorms = prediction *  train_std + train_mean

train_df_orig = df[0:int(n*0.7)]

new_preds = []
for z in range(0, len(preds)):
  ans = preds[z] * train_df_orig.std() + train_df_orig.mean()
  ans = ans.to_numpy()
  new_preds.append(ans[4])

len(new_preds)

#new_preds
```

Out[ ]:

```
4994
```

In [ ]:

```
column_indices = {name: i for i, name in enumerate(df.columns)}

n = len(df)

train_df = df[0:int(n*0.7)]
```

```
val_df = df[int(n*0.7):int(n*0.9)]
test_df = df[-5000:]

num_features = df.shape[1]
```

CSV File

Create and populate .csv file with predictions

In [ ]:
```
predict_DF = pd.DataFrame(new_preds)
predict_DF = predict_DF.reset_index()
predict_DF.columns = ('id','prediction')
predict_DF['id'] = predict_DF['id'] + 1
predict_DF.to_csv('predictions.csv', index=False)
```

Download .csv file from Google Colab

In [ ]:
```
from google.colab import files
files.download('predictions.csv')
```