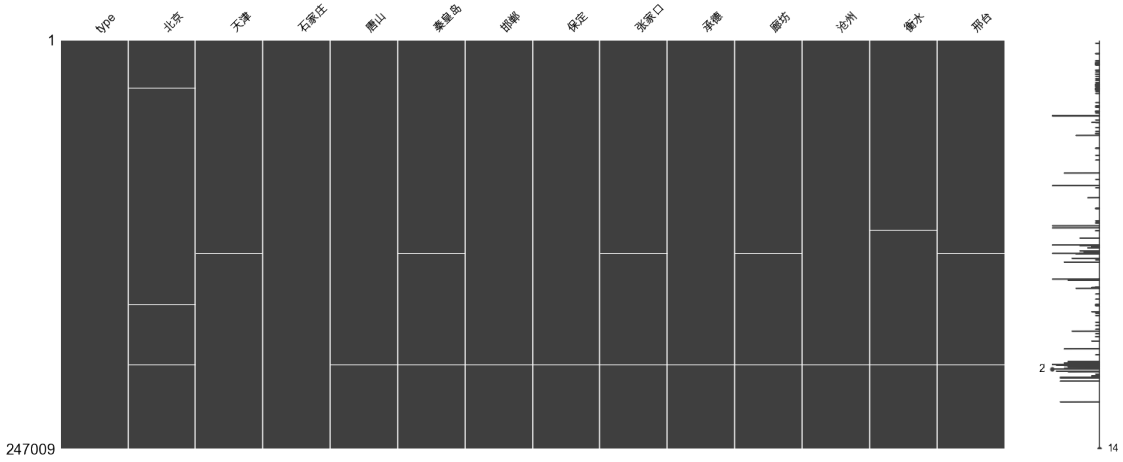
lstm_128_dense_1

May 8, 2022

[ ]:
```
# referrence:  https://keras.io/examples/timeseries/
 ↪timeseries_weather_forecasting/
import numpy as np
import pandas as pd
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import matplotlib.pyplot as plt
import missingno as msno
plt.rcParams['font.sans-serif'] = ['Arial Unicode MS']
```

[ ]:
```
DATA_DIR = '../../data/data_clean.csv'
raw_df = pd.read_csv(DATA_DIR)
raw_df.columns
raw_df = raw_df.drop(['Source.Name','date','hour','tag'],axis=1)
```

[ ]:
```
msno.matrix(raw_df);
```



0.0.1 O3

[ ]:
```
O3 = raw_df[raw_df['type']=='O3_24h'].drop('type',axis=1)
O3['label'] = O3[' '].shift(-15)
O3 = O3.dropna()
```

[ ]:
```
df = O3
df.shape
```

[ ]:
```
(60932, 14)
```

[ ]:
```
split_fraction = 0.725
train_split = int(split_fraction * int(df.shape[0]))
step = 1

past = 200
future = 15
learning_rate = 0.00001
batch_size = 256
epochs = 50
```

[ ]:
```
def normalize(data, train_split):
    data_mean = data[:train_split].mean(axis=0)
    data_std = data[:train_split].std(axis=0)
    return (data - data_mean) / data_std
```

[ ]:
```
features = df.drop(['label'],axis=1)
features = normalize(features.values, train_split)
features = pd.DataFrame(features)
features.head()

train_data = features.loc[0 : train_split - 1]
val_data = features.loc[train_split:]
```

[ ]:
```
start = past + future
end = start + train_split

x_train = train_data.values
y_train = features.iloc[start:end][[1]]

sequence_length = 200
```

[ ]:
```
dataset_train = keras.preprocessing.timeseries_dataset_from_array(
    x_train,
    y_train,
    sequence_length=sequence_length,
    # sampling_rate=step,
```

```
    batch_size=batch_size,
)
```

```
Metal device set to: Apple M1 Pro

systemMemory: 16.00 GB
maxCacheSize: 5.33 GB


2022-05-08 22:19:35.017335: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:305]
Could not identify NUMA node of platform GPU ID 0, defaulting to 0. Your kernel
may not have been built with NUMA support.
2022-05-08 22:19:35.017652: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:271]
Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 0
MB memory) -> physical PluggableDevice (device: 0, name: METAL, pci bus id:
<undefined>)
```

[ ]:
```
x_end = len(val_data) - past - future

label_start = train_split + past + future

x_val = val_data.iloc[:x_end,:].values
y_val = features.iloc[label_start:][[1]]

dataset_val = keras.preprocessing.timeseries_dataset_from_array(
    x_val,
    y_val,
    sequence_length=sequence_length,
    # sampling_rate=step,
    batch_size=batch_size,
)


for batch in dataset_val.take(1):
    inputs, targets = batch

print("Input shape:", inputs.numpy().shape)
print("Target shape:", targets.numpy().shape)
```

```
Input shape: (256, 200, 13)
Target shape: (256, 1)

2022-05-08 22:19:35.127594: W
tensorflow/core/platform/profile_utils/cpu_utils.cc:128] Failed to get CPU
frequency: 0 Hz
```

[ ]:
```
inputs = keras.layers.Input(shape=(inputs.shape[1], inputs.shape[2]))
lstm_out = keras.layers.LSTM(128)(inputs)
outputs = keras.layers.Dense(1)(lstm_out)

model = keras.Model(inputs=inputs, outputs=outputs)
model.compile(optimizer=keras.optimizers.Adam(learning_rate=learning_rate),␣
 ↪loss="mse")
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 200, 13)]         0

 lstm (LSTM)                 (None, 128)               72704

 dense (Dense)               (None, 1)                 129

=================================================================
Total params: 72,833
Trainable params: 72,833
Non-trainable params: 0
_________________________________________________________________
```

[ ]:
```
# path_checkpoint = "model_checkpoint.h5"
es_callback = keras.callbacks.EarlyStopping(monitor="val_loss", min_delta=0,␣
 ↪patience=5)
# tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir="./logs")
modelckpt_callback = keras.callbacks.ModelCheckpoint(
    monitor="val_loss",
    # filepath=path_checkpoint,
    verbose=1,
    save_weights_only=True,
    save_best_only=True,
)

history = model.fit(
    dataset_train,
    epochs=epochs,
    validation_data=dataset_val,
    callbacks=[es_callback,
               modelckpt_callback]
            #    tensorboard_callback],
)
```

```
Epoch 1/50
```

```
2022-05-08 22:19:35.944496: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
2022-05-08 22:19:36.069282: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
2022-05-08 22:19:36.545478: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.

172/172 [==============================] - ETA: 0s - loss: 0.6651

2022-05-08 22:19:49.637179: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
2022-05-08 22:19:49.682863: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.


Epoch 1: val_loss improved from inf to 0.43295, saving model to
model_checkpoint.h5
172/172 [==============================] - 17s 87ms/step - loss: 0.6651 -
val_loss: 0.4330
Epoch 2/50
172/172 [==============================] - ETA: 0s - loss: 0.5162
Epoch 2: val_loss improved from 0.43295 to 0.34017, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.5162 -
val_loss: 0.3402
Epoch 3/50
172/172 [==============================] - ETA: 0s - loss: 0.4248
Epoch 3: val_loss improved from 0.34017 to 0.28544, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 79ms/step - loss: 0.4248 -
val_loss: 0.2854
Epoch 4/50
172/172 [==============================] - ETA: 0s - loss: 0.3736
Epoch 4: val_loss improved from 0.28544 to 0.25765, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 79ms/step - loss: 0.3736 -
val_loss: 0.2577
Epoch 5/50
172/172 [==============================] - ETA: 0s - loss: 0.3491
Epoch 5: val_loss improved from 0.25765 to 0.24616, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 80ms/step - loss: 0.3491 -
val_loss: 0.2462
Epoch 6/50
```

```
172/172 [==============================] - ETA: 0s - loss: 0.3390
Epoch 6: val_loss improved from 0.24616 to 0.24245, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3390 -
val_loss: 0.2424
Epoch 7/50
172/172 [==============================] - ETA: 0s - loss: 0.3351
Epoch 7: val_loss improved from 0.24245 to 0.24150, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 87ms/step - loss: 0.3351 -
val_loss: 0.2415
Epoch 8/50
172/172 [==============================] - ETA: 0s - loss: 0.3332
Epoch 8: val_loss improved from 0.24150 to 0.24122, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 84ms/step - loss: 0.3332 -
val_loss: 0.2412
Epoch 9/50
172/172 [==============================] - ETA: 0s - loss: 0.3317
Epoch 9: val_loss improved from 0.24122 to 0.24098, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.3317 -
val_loss: 0.2410
Epoch 10/50
172/172 [==============================] - ETA: 0s - loss: 0.3302
Epoch 10: val_loss improved from 0.24098 to 0.24068, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 84ms/step - loss: 0.3302 -
val_loss: 0.2407
Epoch 11/50
172/172 [==============================] - ETA: 0s - loss: 0.3287
Epoch 11: val_loss improved from 0.24068 to 0.24033, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.3287 -
val_loss: 0.2403
Epoch 12/50
172/172 [==============================] - ETA: 0s - loss: 0.3271
Epoch 12: val_loss improved from 0.24033 to 0.23994, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 79ms/step - loss: 0.3271 -
val_loss: 0.2399
Epoch 13/50
172/172 [==============================] - ETA: 0s - loss: 0.3255
Epoch 13: val_loss improved from 0.23994 to 0.23954, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.3255 -
val_loss: 0.2395
Epoch 14/50
```

```
172/172 [==============================] - ETA: 0s - loss: 0.3239
Epoch 14: val_loss improved from 0.23954 to 0.23913, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 84ms/step - loss: 0.3239 -
val_loss: 0.2391
Epoch 15/50
172/172 [==============================] - ETA: 0s - loss: 0.3223
Epoch 15: val_loss improved from 0.23913 to 0.23870, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.3223 -
val_loss: 0.2387
Epoch 16/50
172/172 [==============================] - ETA: 0s - loss: 0.3206
Epoch 16: val_loss improved from 0.23870 to 0.23825, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 80ms/step - loss: 0.3206 -
val_loss: 0.2382
Epoch 17/50
172/172 [==============================] - ETA: 0s - loss: 0.3189
Epoch 17: val_loss improved from 0.23825 to 0.23778, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3189 -
val_loss: 0.2378
Epoch 18/50
172/172 [==============================] - ETA: 0s - loss: 0.3172
Epoch 18: val_loss improved from 0.23778 to 0.23730, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 80ms/step - loss: 0.3172 -
val_loss: 0.2373
Epoch 19/50
172/172 [==============================] - ETA: 0s - loss: 0.3155
Epoch 19: val_loss improved from 0.23730 to 0.23679, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3155 -
val_loss: 0.2368
Epoch 20/50
172/172 [==============================] - ETA: 0s - loss: 0.3137
Epoch 20: val_loss improved from 0.23679 to 0.23625, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3137 -
val_loss: 0.2363
Epoch 21/50
172/172 [==============================] - ETA: 0s - loss: 0.3119
Epoch 21: val_loss improved from 0.23625 to 0.23570, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3119 -
val_loss: 0.2357
Epoch 22/50
```

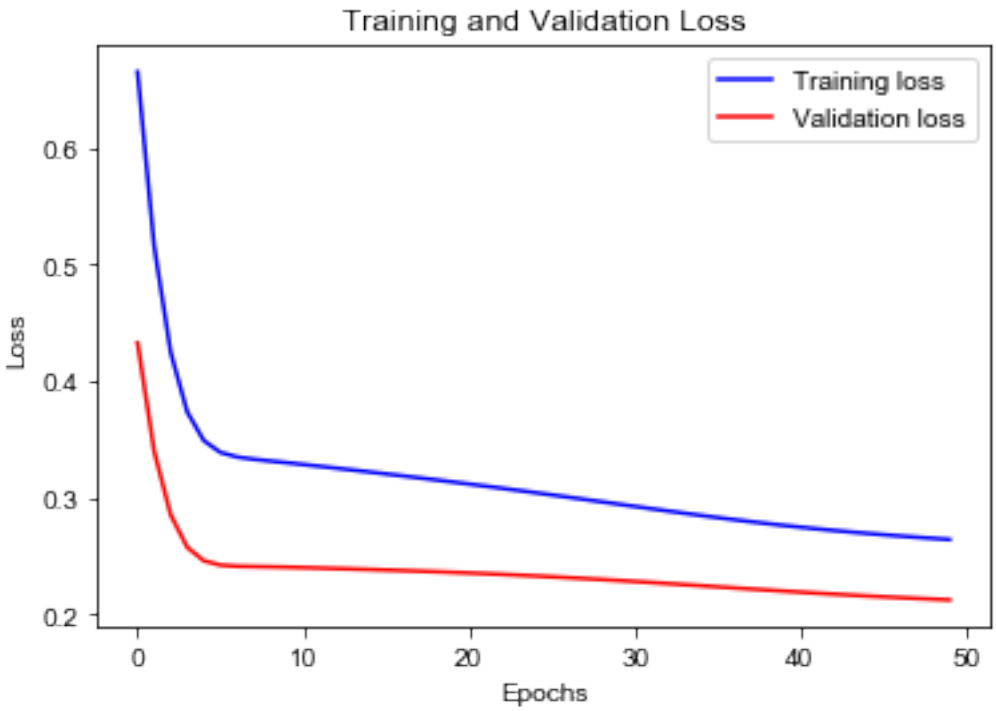
```
172/172 [==============================] - ETA: 0s - loss: 0.3101
Epoch 22: val_loss improved from 0.23570 to 0.23511, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.3101 -
val_loss: 0.2351
Epoch 23/50
172/172 [==============================] - ETA: 0s - loss: 0.3083
Epoch 23: val_loss improved from 0.23511 to 0.23449, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.3083 -
val_loss: 0.2345
Epoch 24/50
172/172 [==============================] - ETA: 0s - loss: 0.3064
Epoch 24: val_loss improved from 0.23449 to 0.23384, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3064 -
val_loss: 0.2338
Epoch 25/50
172/172 [==============================] - ETA: 0s - loss: 0.3045
Epoch 25: val_loss improved from 0.23384 to 0.23316, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.3045 -
val_loss: 0.2332
Epoch 26/50
172/172 [==============================] - ETA: 0s - loss: 0.3026
Epoch 26: val_loss improved from 0.23316 to 0.23245, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.3026 -
val_loss: 0.2325
Epoch 27/50
172/172 [==============================] - ETA: 0s - loss: 0.3006
Epoch 27: val_loss improved from 0.23245 to 0.23171, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.3006 -
val_loss: 0.2317
Epoch 28/50
172/172 [==============================] - ETA: 0s - loss: 0.2987
Epoch 28: val_loss improved from 0.23171 to 0.23093, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2987 -
val_loss: 0.2309
Epoch 29/50
172/172 [==============================] - ETA: 0s - loss: 0.2967
Epoch 29: val_loss improved from 0.23093 to 0.23013, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 84ms/step - loss: 0.2967 -
val_loss: 0.2301
Epoch 30/50
```

```
172/172 [==============================] - ETA: 0s - loss: 0.2947
Epoch 30: val_loss improved from 0.23013 to 0.22929, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2947 -
val_loss: 0.2293
Epoch 31/50
172/172 [==============================] - ETA: 0s - loss: 0.2927
Epoch 31: val_loss improved from 0.22929 to 0.22843, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.2927 -
val_loss: 0.2284
Epoch 32/50
172/172 [==============================] - ETA: 0s - loss: 0.2908
Epoch 32: val_loss improved from 0.22843 to 0.22755, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 81ms/step - loss: 0.2908 -
val_loss: 0.2276
Epoch 33/50
172/172 [==============================] - ETA: 0s - loss: 0.2888
Epoch 33: val_loss improved from 0.22755 to 0.22665, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2888 -
val_loss: 0.2266
Epoch 34/50
172/172 [==============================] - ETA: 0s - loss: 0.2869
Epoch 34: val_loss improved from 0.22665 to 0.22573, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 85ms/step - loss: 0.2869 -
val_loss: 0.2257
Epoch 35/50
172/172 [==============================] - ETA: 0s - loss: 0.2850
Epoch 35: val_loss improved from 0.22573 to 0.22480, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2850 -
val_loss: 0.2248
Epoch 36/50
172/172 [==============================] - ETA: 0s - loss: 0.2832
Epoch 36: val_loss improved from 0.22480 to 0.22387, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 84ms/step - loss: 0.2832 -
val_loss: 0.2239
Epoch 37/50
172/172 [==============================] - ETA: 0s - loss: 0.2814
Epoch 37: val_loss improved from 0.22387 to 0.22293, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.2814 -
val_loss: 0.2229
Epoch 38/50
```

```
172/172 [==============================] - ETA: 0s - loss: 0.2797
Epoch 38: val_loss improved from 0.22293 to 0.22200, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 84ms/step - loss: 0.2797 -
val_loss: 0.2220
Epoch 39/50
172/172 [==============================] - ETA: 0s - loss: 0.2780
Epoch 39: val_loss improved from 0.22200 to 0.22108, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 84ms/step - loss: 0.2780 -
val_loss: 0.2211
Epoch 40/50
172/172 [==============================] - ETA: 0s - loss: 0.2765
Epoch 40: val_loss improved from 0.22108 to 0.22017, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.2765 -
val_loss: 0.2202
Epoch 41/50
172/172 [==============================] - ETA: 0s - loss: 0.2749
Epoch 41: val_loss improved from 0.22017 to 0.21928, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2749 -
val_loss: 0.2193
Epoch 42/50
172/172 [==============================] - ETA: 0s - loss: 0.2735
Epoch 42: val_loss improved from 0.21928 to 0.21842, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 88ms/step - loss: 0.2735 -
val_loss: 0.2184
Epoch 43/50
172/172 [==============================] - ETA: 0s - loss: 0.2722
Epoch 43: val_loss improved from 0.21842 to 0.21759, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 87ms/step - loss: 0.2722 -
val_loss: 0.2176
Epoch 44/50
172/172 [==============================] - ETA: 0s - loss: 0.2709
Epoch 44: val_loss improved from 0.21759 to 0.21679, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2709 -
val_loss: 0.2168
Epoch 45/50
172/172 [==============================] - ETA: 0s - loss: 0.2697
Epoch 45: val_loss improved from 0.21679 to 0.21602, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2697 -
val_loss: 0.2160
Epoch 46/50
```

```
172/172 [==============================] - ETA: 0s - loss: 0.2685
Epoch 46: val_loss improved from 0.21602 to 0.21528, saving model to
model_checkpoint.h5
172/172 [==============================] - 15s 84ms/step - loss: 0.2685 -
val_loss: 0.2153
Epoch 47/50
172/172 [==============================] - ETA: 0s - loss: 0.2674
Epoch 47: val_loss improved from 0.21528 to 0.21458, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 80ms/step - loss: 0.2674 -
val_loss: 0.2146
Epoch 48/50
172/172 [==============================] - ETA: 0s - loss: 0.2664
Epoch 48: val_loss improved from 0.21458 to 0.21391, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 83ms/step - loss: 0.2664 -
val_loss: 0.2139
Epoch 49/50
172/172 [==============================] - ETA: 0s - loss: 0.2654
Epoch 49: val_loss improved from 0.21391 to 0.21328, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 84ms/step - loss: 0.2654 -
val_loss: 0.2133
Epoch 50/50
172/172 [==============================] - ETA: 0s - loss: 0.2644
Epoch 50: val_loss improved from 0.21328 to 0.21268, saving model to
model_checkpoint.h5
172/172 [==============================] - 14s 82ms/step - loss: 0.2644 -
val_loss: 0.2127
```

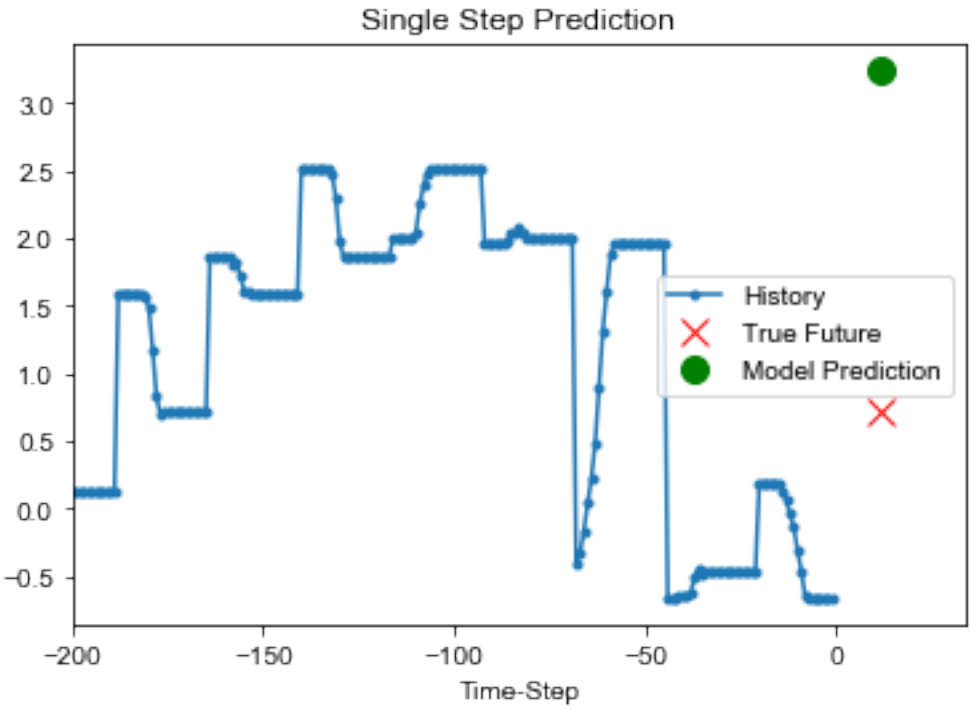
[ ]:
```python
def visualize_loss(history, title):
    loss = history.history["loss"]
    val_loss = history.history["val_loss"]
    epochs = range(len(loss))
    plt.figure()
    plt.plot(epochs, loss, "b", label="Training loss")
    plt.plot(epochs, val_loss, "r", label="Validation loss")
    plt.title(title)
    plt.xlabel("Epochs")
    plt.ylabel("Loss")
    plt.legend()
    plt.show()


visualize_loss(history, "Training and Validation Loss")
```

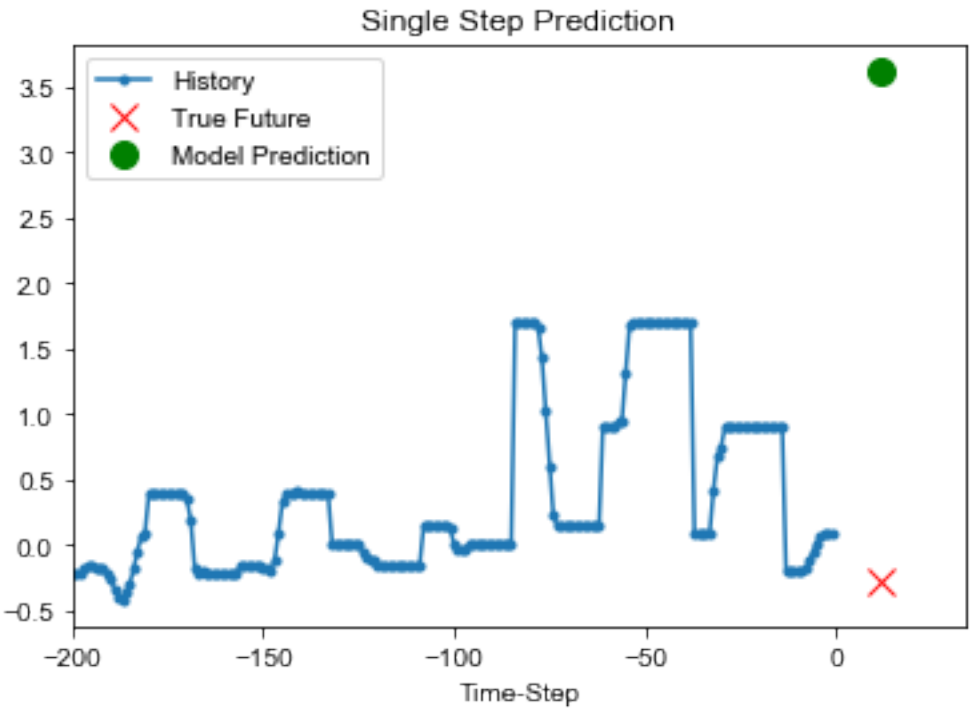


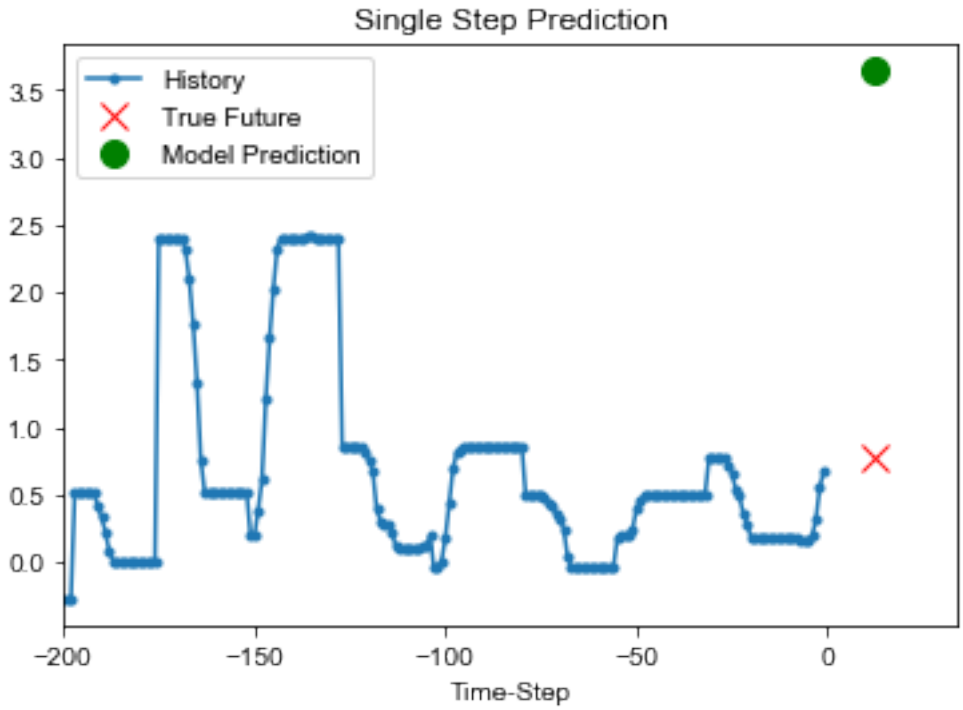
[ ]:
```
def show_plot(plot_data, delta, title):
    labels = ["History", "True Future", "Model Prediction"]
    marker = [".-", "rx", "go"]
    time_steps = list(range(-(plot_data[0].shape[0]), 0))
    if delta:
        future = delta
    else:
        future = 0

    plt.title(title)
    for i, val in enumerate(plot_data):
        if i:
            plt.plot(future, plot_data[i], marker[i], markersize=10,␣
 ↪label=labels[i])
        else:
            plt.plot(time_steps, plot_data[i].flatten(), marker[i],␣
 ↪label=labels[i])
    plt.legend()
    plt.xlim([time_steps[0], (future + 5) * 2])
    plt.xlabel("Time-Step")
    plt.show()
    return
```

[ ]:
```
for x, y in dataset_val.take(3):
    show_plot(
        [x[0][:, 1].numpy(), y[0].numpy(), model.predict(x)[0]],
        12,
        "Single Step Prediction",
    )
```

```
2022-05-08 22:31:30.036899: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
2022-05-08 22:31:30.074534: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
```




Single Step Prediction
History
True Future
Model Prediction
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−200
−150
−100
−50
0
Time-Step

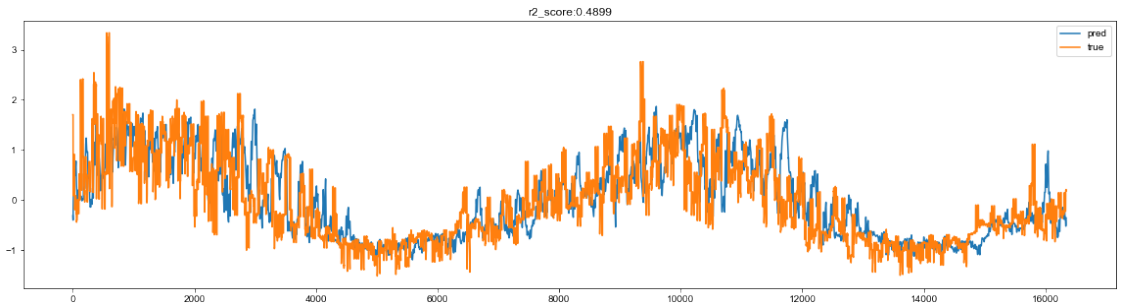

Single Step Prediction
History
True Future
Model Prediction
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−200
−150
−100
−50
0
Time-Step

[ ]:
```
pred = model.predict(dataset_val)
```

```
2022-05-08 22:31:31.306829: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
2022-05-08 22:31:31.351279: I
tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113]
Plugin optimizer for device_type GPU is enabled.
```

[ ]:
```
from sklearn.metrics import r2_score
y_pred = pred
y_true = y_val.values.flatten()[-len(y_pred):]
plt.figure(figsize=(20, 5))
plt.plot(y_pred,label = 'pred')
plt.plot(y_true,label='true')
plt.legend()
plt.title('r2_score:{:.4f}'.format(r2_score(y_true,y_pred)))
```

[ ]:
```
Text(0.5, 1.0, 'r2_score:0.4899')
```



[ ]:
```
model.save('./models/lstm_128_dense_1.h5')
```

[ ]:
```
```