lstm_multivariate_to_single_feature

May 29, 2023

1 SINGLE PREDICTION USING MULTIVARIATE FEATURES WITH LSTM SEQ2SEQ

1.1 HERE WE USED: 12h for running the running inference over the next 1h

[54]:
```
import tensorflow as tf
# Data Loader Parameters
BATCH_SIZE = 128
BUFFER_SIZE = 100

# LSTM Parameters
EVALUATION_INTERVAL = 200
PATIENCE = 10

PAST_WINDOW_SIZE = 144                    # ----------- 12H
FUTURE_WINDOW_SIZE = 12                   # ----------- 1H
STEP = 3

# Reproducibility
SEED = 13
tf.random.set_seed(SEED)
```

[55]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn import preprocessing
from keras.models import Sequential, save_model, load_model
from keras.layers import Bidirectional, LSTM, Dropout, Dense
from sklearn.metrics import mean_squared_error
from math import sqrt
from sklearn.metrics import mean_absolute_percentage_error
import os
import time
from tensorflow.keras.callbacks import CSVLogger, EarlyStopping
from tensorflow.keras.layers import BatchNormalization, ConvLSTM2D, RepeatVector
from keras.layers.core import Dense, Dropout, Activation, Flatten, Reshape
```

```
from tensorflow.keras.layers import TimeDistributed

# physical_devices = tf.config.list_physical_devices('GPU')
# tf.config.experimental.set_memory_growth(physical_devices[0], enable=True)

# read dataset may2023
df = pd.read_pickle("../../data/20230319_RTU_Dataset_PPC-Lab/combined_may2023.
 ↪pkl")
```

[56]:
```
def create_sequence(dataset, target, window, future):
    x_sequence, y_sequence = [], []
    for index in range(len(dataset) - window - future):
        x_sequence.append(dataset[index: index + window])
        y_sequence.append(target[index + window: index + window + future])
    return (np.asarray(x_sequence), np.asarray(y_sequence))

def plot_train_history(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.legend()

    plt.show()

def multivariate_multioutput_data(dataset, target, start_index, end_index,␣
 ↪history_size, target_size, step):
    data = []
    labels = []

    start_index = start_index + history_size
    if end_index is None:
        end_index = len(dataset) - target_size

    for i in range(start_index, end_index):
        indices = range(i-history_size, i, step)
        data.append(dataset[indices])
        labels.append(target[i:i+target_size])

    return np.array(data)[:,:,:,np.newaxis,np.newaxis], np.array(labels)[:,:,:
 ↪,np.newaxis,np.newaxis]
```

```
def multi_step_plot(history, true_future, prediction):
    plt.figure(figsize=(18, 6))
    num_in = create_time_steps(len(history))
    num_out = len(true_future)

    plt.plot(num_in, np.array(history[:, 1]), label='History')
    plt.plot(np.arange(num_out)/STEP, np.array(true_future), 'bo',
           label='True Future')
    if prediction.any():
        plt.plot(np.arange(num_out)/STEP, np.array(prediction), 'ro',
                 label='Predicted Future')
    plt.legend(loc='upper left')
    plt.show()

def create_time_steps(length):
    return list(range(-length, 0))

def multivariate_data(dataset, target, start_index, end_index, history_size,
                      target_size, step, single_step=False):
    data = []
    labels = []

    start_index = start_index + history_size
    if end_index is None:
        end_index = len(dataset) - target_size

    for i in range(start_index, end_index):
        indices = range(i-history_size, i, step)
        data.append(dataset[indices])

        if single_step:
            labels.append(target[i+target_size])
        else:
            labels.append(target[i:i+target_size])

    return np.array(data), np.array(labels)

def evaluate_predictions(predictions_seq, y_test_seq):
    MSE = []
    for pred in range(len(y_test)):
        mse = mean_squared_error(y_test_seq[pred], predictions_seq[pred])
        MSE.append(mse)
    return MSE

def find_max_error(predictions, y_test, mean_mse, std_mse):
    max_errors = 0
```

```
    for pred in range(len(y_test)):
        mse = mean_squared_error(y_test[pred], predictions[pred])
    if mse > mean_mse + std_mse:
        max_errors += 1
    return max_errors

def build_model(input_timesteps, output_timesteps, num_links, num_inputs):
    model = Sequential()
    model.add(BatchNormalization(name = 'batch_norm_0', input_shape =␣
 ↪(input_timesteps, num_inputs, 1, 1)))
    model.add(ConvLSTM2D(name ='conv_lstm_1',
                         filters = 64, kernel_size = (10, 1),
                         padding = 'same',
                         return_sequences = False))

    model.add(Dropout(0.30, name = 'dropout_1'))
    model.add(BatchNormalization(name = 'batch_norm_1'))

#     model.add(ConvLSTM2D(name ='conv_lstm_2',
#                          filters = 64, kernel_size = (5, 1),
#                          padding='same',
#                          return_sequences = False))

#     model.add(Dropout(0.20, name = 'dropout_2'))
#     model.add(BatchNormalization(name = 'batch_norm_2'))

    model.add(Flatten())
    model.add(RepeatVector(output_timesteps))
    model.add(Reshape((output_timesteps, num_inputs, 1, 64)))

#     model.add(ConvLSTM2D(name ='conv_lstm_3',
#                          filters = 64, kernel_size = (10, 1),
#                          padding='same',
#                          return_sequences = True))

#     model.add(Dropout(0.20, name = 'dropout_3'))
#     model.add(BatchNormalization(name = 'batch_norm_3'))

    model.add(ConvLSTM2D(name ='conv_lstm_4',
                         filters = 64, kernel_size = (5, 1),
                         padding='same',
                         return_sequences = True))

    model.add(TimeDistributed(Dense(units=1, name = 'dense_1', activation =␣
 ↪'relu')))
    model.add(Dense(units=1, name = 'dense_2'))
```

```
#     optimizer = RMSprop() #lr=0.0001, rho=0.9, epsilon=1e-08, decay=0.9)
#     optimizer = tf.keras.optimizers.Adam(0.1)
    optimizer = tf.keras.optimizers.RMSprop(lr=0.003, clipvalue=1.0)
    model.compile(loss = "mse", optimizer = optimizer, metrics = ['mae', 'mse'])
    return model

def my_mean_absolute_percentage_error(y_true, y_pred):
    error = 0
    for i in range(len(y_true)):
        if y_true[i] != 0:
            error += abs((y_true[i] - y_pred[i]) / y_true[i])

    mape = (error / len(y_true)) * 100
    return mape
```

[57]:
```
# Normalizing the values
standard_scaler = preprocessing.StandardScaler()
print(df.head())
scaled_df = standard_scaler.fit_transform(df[['MEM_USAGE', 'CPU_USAGE',␣
 ↪'TEMP']])
print(scaled_df[:10])
print(scaled_df[:,1])

training_size = int(len(scaled_df) * 0.8)

print('Size of the dataset: %d' % (len(scaled_df)))
print('Size of training: %d' % (training_size))
```

```
   MEM_USAGE  CPU_USAGE     PS1_V    TEMP
0  35.555417  27.343750  5.435294  28.687
1  35.555417   6.367041  5.435294  28.687
2  35.555417   7.142857  5.435294  28.687
3  35.555417  27.306273  5.435294  28.687
4  35.555417   5.639098  5.435294  28.687
[[ 0.48139574  1.13540371  0.74576055]
 [ 0.48139574 -0.66263387  0.74576055]
 [ 0.48139574 -0.59613411  0.74576055]
 [ 0.48139574  1.13219134  0.74576055]
 [ 0.48139574 -0.7250302   0.74576055]
 [ 0.48139574 -0.73742406  0.74576055]
 [ 0.48139574 -0.6369512   0.74576055]
 [ 0.48139574 -0.91168167  0.74576055]
 [ 0.48139574 -0.63268673  0.74576055]
 [ 0.48139574 -0.27087286  0.74576055]]
[ 1.13540371 -0.66263387 -0.59613411 … -0.69409514 -0.51872237
 -0.07440583]
Size of the dataset: 3733
```

```
Size of training: 2986
```

[58]:
```
scaled_df
```

[58]:
```
array([[ 0.48139574,  1.13540371,  0.74576055],
       [ 0.48139574, -0.66263387,  0.74576055],
       [ 0.48139574, -0.59613411,  0.74576055],
       …,
       [-1.80536352, -0.69409514,  0.98794801],
       [-1.80536352, -0.51872237,  0.98794801],
       [-1.80536352, -0.07440583,  0.98794801]])
```

2 MULTIVARIATE TO SINGLE FEATURE CPU

[59]:
```
x_train_multi, y_train_multi = multivariate_data(scaled_df, scaled_df[:, 1], 0,
                                                 training_size,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
x_val_multi, y_val_multi = multivariate_data(scaled_df, scaled_df[:, 1],
                                             training_size, None,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
```

[60]:
```
x_train_multi.shape
```

[60]:
```
(2842, 48, 3)
```

[61]:
```
y_train_multi.shape
```

[61]:
```
(2842, 12)
```

[62]:
```
train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
train_data_multi = train_data_multi.cache().shuffle(BUFFER_SIZE).
 ↪batch(BATCH_SIZE).repeat()

val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE).repeat()
```

[63]:
```
multi_step_model = tf.keras.models.Sequential()
multi_step_model.add(tf.keras.layers.LSTM(32,
                                          return_sequences=True,
                                          input_shape=x_train_multi.shape[-2:]))
multi_step_model.add(tf.keras.layers.LSTM(16, activation='relu'))
multi_step_model.add(tf.keras.layers.Dense(FUTURE_WINDOW_SIZE))
```

```
multi_step_model.compile(optimizer=tf.keras.optimizers.RMSprop(clipvalue=1.0),␣
  ↪loss='mae')
print(multi_step_model.summary())
```

```
WARNING:tensorflow:Layer lstm_5 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_4 (LSTM)               (None, 48, 32)            4608

 lstm_5 (LSTM)               (None, 16)                3136

 dense_2 (Dense)             (None, 12)                204

=================================================================
Total params: 7,948
Trainable params: 7,948
Non-trainable params: 0
_________________________________________________________________
None
```

```
2023-05-29 17:45:38.032195: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:45:38.032773: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:45:38.033405: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

[64]:
```
for x, y in val_data_multi.take(1):
    print (multi_step_model.predict(x).shape)
```

```
2023-05-29 17:45:39.133956: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
```

```
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:45:39.320276: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:45:39.320920: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:45:39.321522: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

4/4 [==============================] - 0s 5ms/step
(128, 12)
```

[65]:
```
EPOCHS = 10

early_stopping = EarlyStopping(monitor='val_loss', patience = 3,␣
 ↪restore_best_weights=True)
multi_step_history = multi_step_model.fit(train_data_multi,
                                          epochs=EPOCHS,
                                          steps_per_epoch=EVALUATION_INTERVAL,
                                          validation_data=val_data_multi,
                                          validation_steps=EVALUATION_INTERVAL,
                                          callbacks=[early_stopping])
```

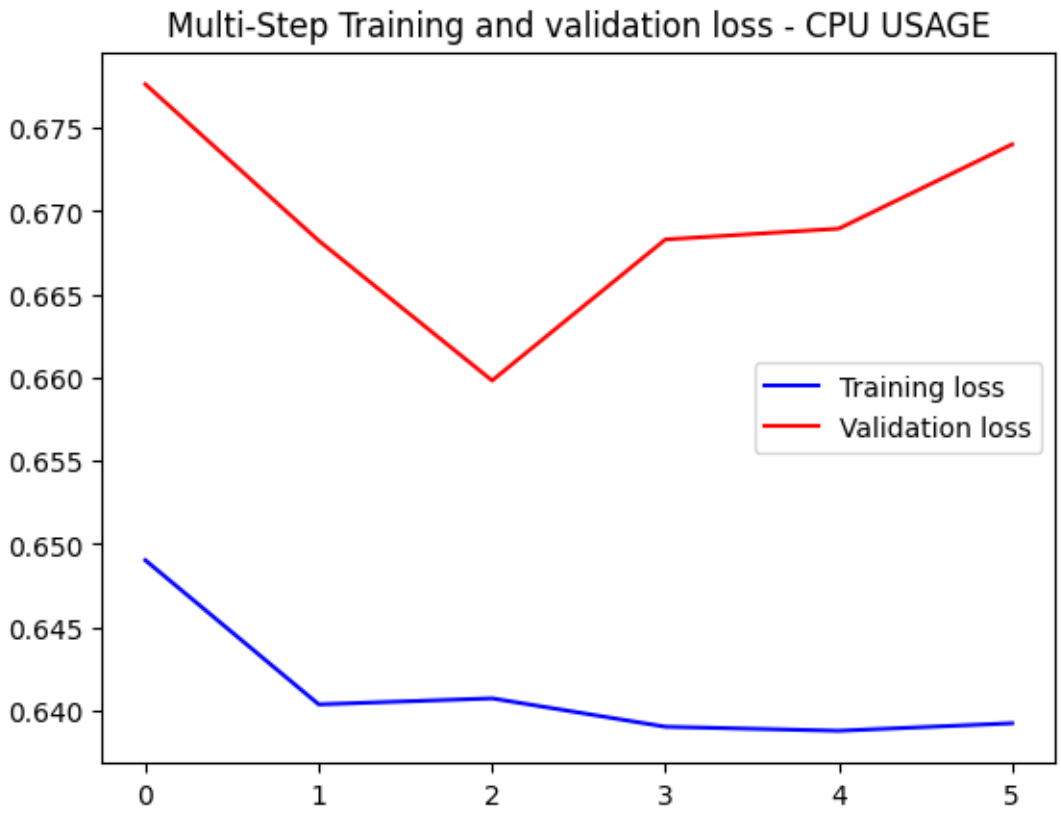
```
Epoch 1/10

2023-05-29 17:45:42.257556: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_0' with dtype double and shape [2842,48,3]
         [[{{node Placeholder/_0}}]]
2023-05-29 17:45:42.603098: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:45:42.603820: I tensorflow/core/common_runtime/executor.cc:1197]
```

```
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:45:42.604574: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:45:43.060790: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:45:43.061644: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:45:43.062375: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

198/200 [============================>.] - ETA: 0s - loss: 0.6492

2023-05-29 17:45:48.340293: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:45:48.447385: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:45:48.448091: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
```

```
2023-05-29 17:45:48.448737: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
200/200 [==============================] - 8s 31ms/step - loss: 0.6490 -
val_loss: 0.6776
Epoch 2/10
200/200 [==============================] - 5s 27ms/step - loss: 0.6404 -
val_loss: 0.6682
Epoch 3/10
200/200 [==============================] - 5s 27ms/step - loss: 0.6407 -
val_loss: 0.6598
Epoch 4/10
200/200 [==============================] - 5s 26ms/step - loss: 0.6390 -
val_loss: 0.6683
Epoch 5/10
200/200 [==============================] - 5s 26ms/step - loss: 0.6388 -
val_loss: 0.6689
Epoch 6/10
200/200 [==============================] - 5s 26ms/step - loss: 0.6392 -
val_loss: 0.6740
```

[66]:
```
multi_step_model.save('best_multistep_multivariate_to_single_cpu.h5')
```

[67]:
```
plot_train_history(multi_step_history, 'Multi-Step Training and validation loss␣
↪- CPU USAGE')
```



[69]:
```
from tensorflow import keras
multi_step_model = keras.models.load_model("./
  ↪best_multistep_multivariate_to_single_cpu.h5")
```

```
WARNING:tensorflow:Layer lstm_5 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.

2023-05-29 17:46:38.798674: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:46:38.799268: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:46:38.800014: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
```

```
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

[ ]:
```
for x, y in val_data_multi.take(3):
    multi_step_plot(x[0], y[0], multi_step_model.predict(x)[0])
```

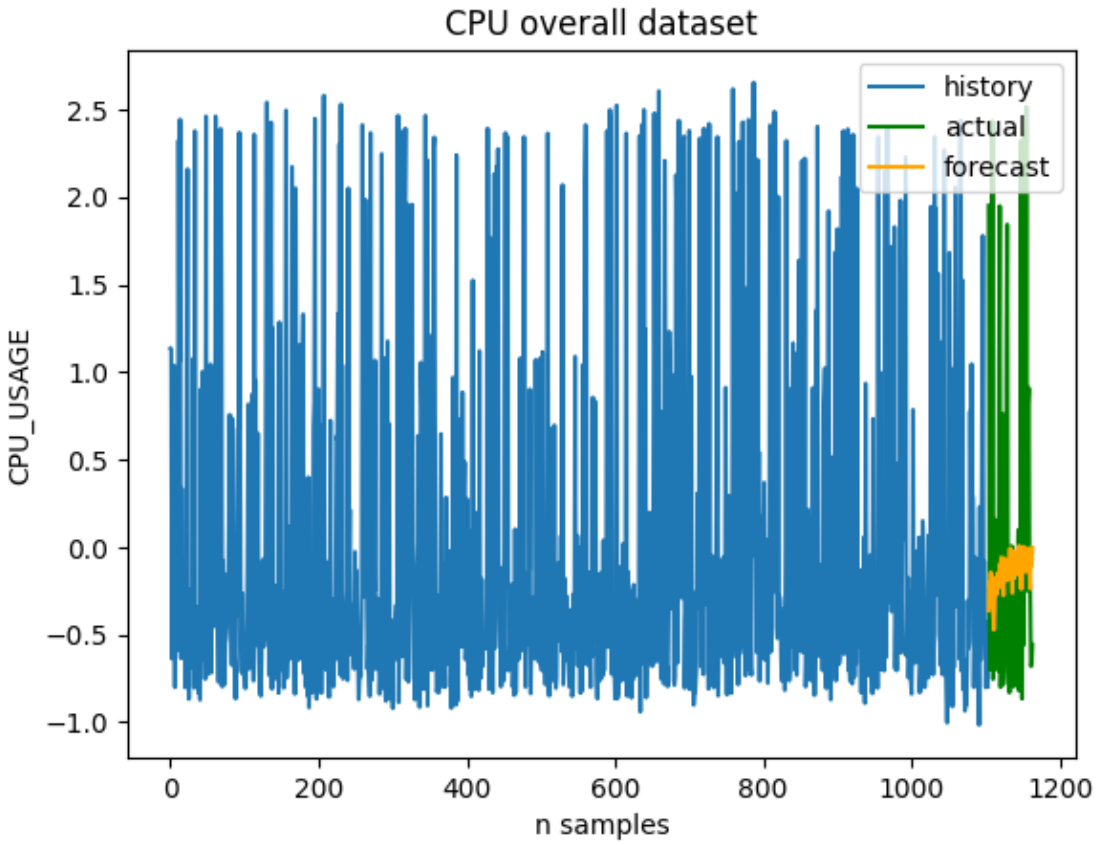
[70]:
```
import tensorflow as tf
train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
train_data_multi = train_data_multi.cache().batch(BATCH_SIZE)
val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE)

predicted_cpus = []
original_cpus = []
history_cpus = []


for x, y in train_data_multi:
    hx_cpu = np.squeeze(x[0])[:,1]
    history_cpus.append(hx_cpu)

for x, y in val_data_multi:
    prediction = multi_step_model.predict(x, verbose = 0)[0]
    ori_cpus = np.squeeze(y[0])

    predicted_cpus.append(prediction)
    original_cpus.append(ori_cpus)


predicted_cpu_usage = np.concatenate(predicted_cpus, axis=0)
original_cpu_usage = np.concatenate(original_cpus, axis=0)
history_cpu_usage = np.concatenate(history_cpus, axis=0)
```

```
2023-05-29 17:46:42.471024: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [2842,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:46:42.515597: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:46:42.667728: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
```

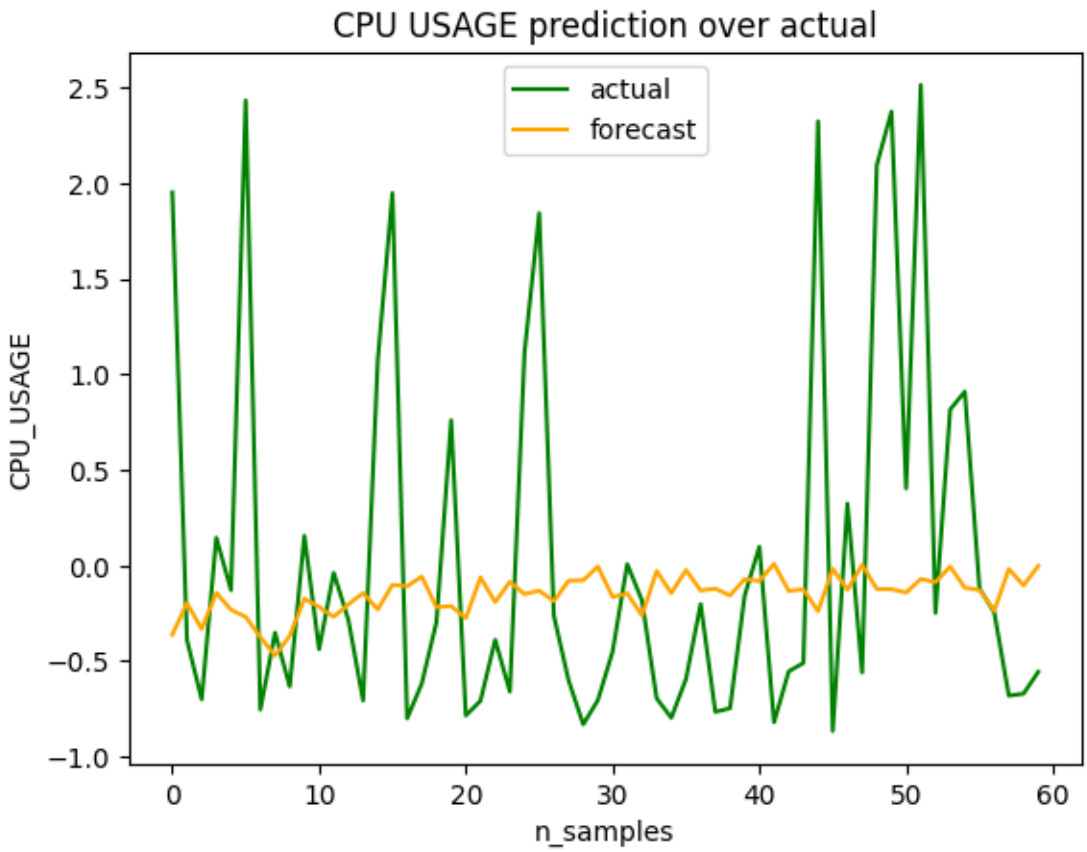
```
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:46:42.668502: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:46:42.669157: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:46:43.137030: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:46:43.137749: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:46:43.138441: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

[71]:
```
plt.title("CPU overall dataset")
plt.xlabel("n samples")
plt.ylabel("CPU_USAGE")
plt.plot(range(len(history_cpu_usage)),history_cpu_usage, label="history")
plt.plot(range(len(history_cpu_usage), len(history_cpu_usage) +␣
 ↪len(predicted_cpu_usage)),original_cpu_usage, label="actual", color="green")
plt.plot(range(len(history_cpu_usage), len(history_cpu_usage) +␣
 ↪len(predicted_cpu_usage)),predicted_cpu_usage, label="forecast" ,␣
 ↪color="orange")

plt.legend()
plt.show()
```

```
x = range(len(predicted_cpu_usage))
plt.title("CPU USAGE prediction over actual")
plt.xlabel("n_samples")
plt.ylabel("CPU_USAGE")
plt.plot(x,original_cpu_usage, label="actual", color="green")
plt.plot(x,predicted_cpu_usage, label="forecast", color="orange")
plt.legend()
```



[71]: <matplotlib.legend.Legend at 0x7fea7840cfd0>



[72]:
```
my_mean_absolute_percentage_error(original_cpu_usage, predicted_cpu_usage)
```

[72]:
```
131.56330744349737
```

[73]:
```
from tensorflow.keras.metrics import mean_absolute_percentage_error
mean_absolute_percentage_error(original_cpu_usage, predicted_cpu_usage)
```

[73]:
```
<tf.Tensor: shape=(), dtype=float32, numpy=131.56332>
```

3 MULTIVARIATE TO SINGLE FEATURE RAM

[74]:
```
x_train_multi, y_train_multi = multivariate_data(scaled_df, scaled_df[:, 0], 0,
                                                 training_size,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
x_val_multi, y_val_multi = multivariate_data(scaled_df, scaled_df[:, 0],
                                             training_size, None,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
```

```
BATCH_SIZE = 128

train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
train_data_multi = train_data_multi.cache().shuffle(BUFFER_SIZE).
 ↪batch(BATCH_SIZE).repeat()

val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE).repeat()

multi_step_model = tf.keras.models.Sequential()
multi_step_model.add(tf.keras.layers.LSTM(32,
                                          return_sequences=True,
                                          input_shape=x_train_multi.shape[-2:]))
multi_step_model.add(tf.keras.layers.LSTM(16, activation='relu'))
multi_step_model.add(tf.keras.layers.Dense(FUTURE_WINDOW_SIZE))

multi_step_model.compile(optimizer=tf.keras.optimizers.RMSprop(clipvalue=1.0),␣
 ↪loss='mae')
print(multi_step_model.summary())

early_stopping = EarlyStopping(monitor='val_loss', patience = 3,␣
 ↪restore_best_weights=True)
multi_step_history = multi_step_model.fit(train_data_multi,
                                          epochs=EPOCHS,
                                          steps_per_epoch=EVALUATION_INTERVAL,
                                          validation_data=val_data_multi,
                                          validation_steps=EVALUATION_INTERVAL,
                                          callbacks=[early_stopping])
```

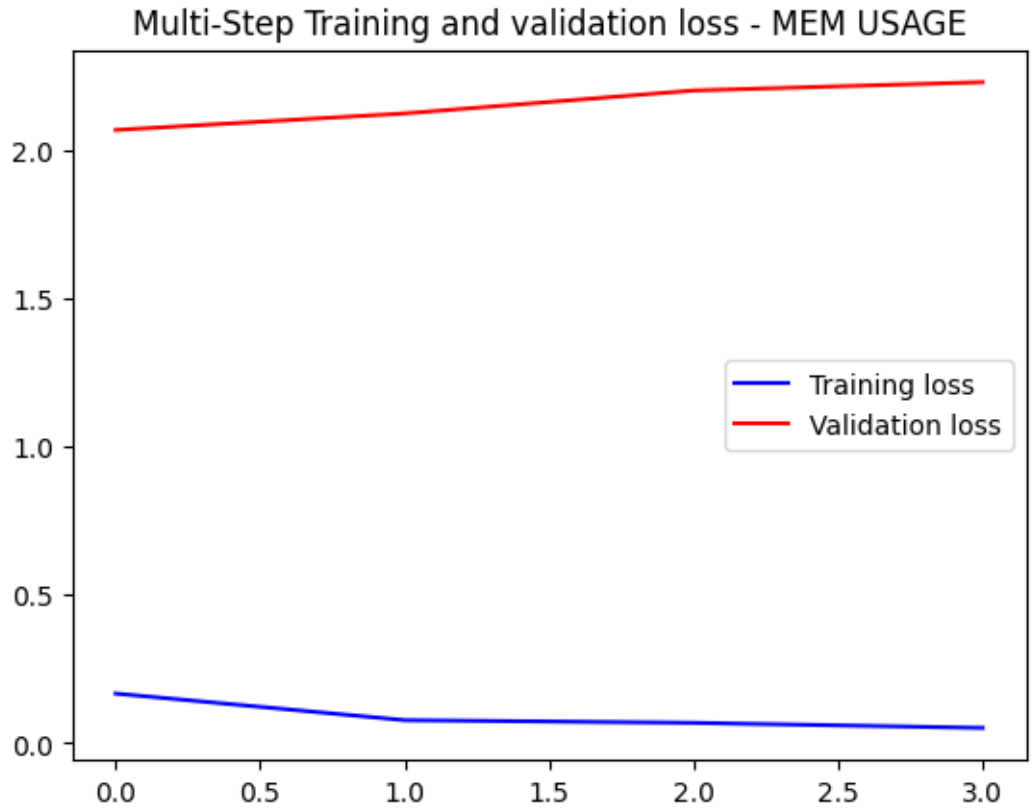
```
WARNING:tensorflow:Layer lstm_7 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                 Output Shape              Param #
=================================================================
 lstm_6 (LSTM)                (None, 48, 32)            4608

 lstm_7 (LSTM)                (None, 16)                3136

 dense_3 (Dense)              (None, 12)                204

=================================================================
Total params: 7,948
Trainable params: 7,948
Non-trainable params: 0
_________________________________________________________________
```

```
None
Epoch 1/10

2023-05-29 17:47:12.616418: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:47:12.617247: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:47:12.617814: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:47:12.669637: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [2842,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:47:12.770643: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:47:12.771496: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:47:12.772188: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:47:13.306586: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
```

```
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:47:13.307278: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:47:13.308139: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

199/200 [============================>.] - ETA: 0s - loss: 0.1682

2023-05-29 17:47:18.583195: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:47:18.685884: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:47:18.686649: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:47:18.687259: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

200/200 [==============================] - 7s 28ms/step - loss: 0.1675 -
val_loss: 2.0665
Epoch 2/10
200/200 [==============================] - 5s 27ms/step - loss: 0.0779 -
val_loss: 2.1222
Epoch 3/10
200/200 [==============================] - 6s 30ms/step - loss: 0.0688 -
val_loss: 2.1995
```

```
Epoch 4/10
200/200 [==============================] - 5s 27ms/step - loss: 0.0518 -
val_loss: 2.2276
```

[75]:
```
plot_train_history(multi_step_history, 'Multi-Step Training and validation loss
 ↪- MEM USAGE')
```



[76]:
```
multi_step_model.save('best_multistep_multivariate_to_single_mem.h5')
```

[77]:
```
from tensorflow import keras
multi_step_model = keras.models.load_model("./
 ↪best_multistep_multivariate_to_single_mem.h5")
```

```
WARNING:tensorflow:Layer lstm_7 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.

2023-05-29 17:48:30.604154: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
```

```
2023-05-29 17:48:30.606636: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:48:30.608619: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

[ ]:
```
for x, y in val_data_multi.take(3):
    multi_step_plot(x[0], y[0], multi_step_model.predict(x)[0])
```

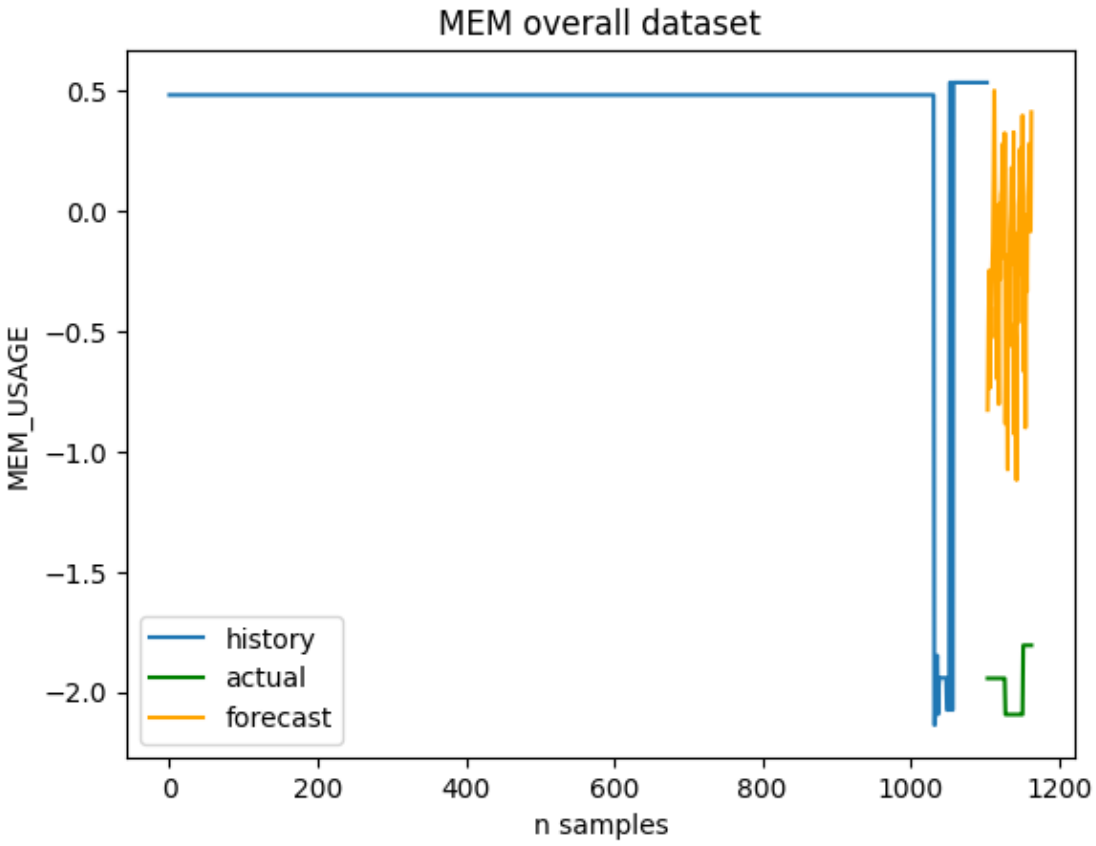
[78]:
```
import tensorflow as tf
train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
train_data_multi = train_data_multi.cache().batch(BATCH_SIZE)
val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE)

predicted_mems = []
original_mems = []
history_mems = []


for x, y in train_data_multi:
    hx_mem = np.squeeze(x[0])[:,0]
    history_mems.append(hx_mem)

for x, y in val_data_multi:
    prediction = multi_step_model.predict(x, verbose = 0)[0]
    ori_mems = np.squeeze(y[0])

    predicted_mems.append(prediction)
    original_mems.append(ori_mems)


predicted_mem_usage = np.concatenate(predicted_mems, axis=0)
original_mem_usage = np.concatenate(original_mems, axis=0)
history_mem_usage = np.concatenate(history_mems, axis=0)
```

```
2023-05-29 17:48:33.482111: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [2842,12]
```

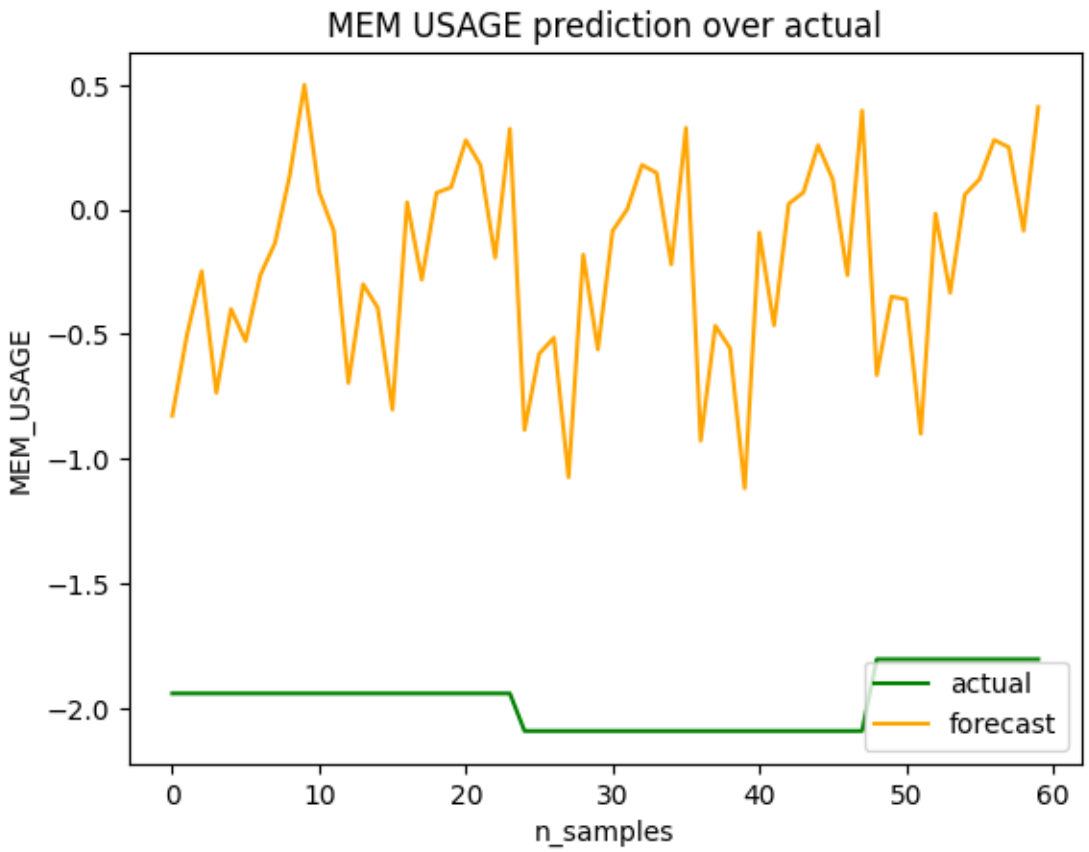
```
         [[{{node Placeholder/_1}}]]
2023-05-29 17:48:33.495677: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:48:33.613514: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:48:33.614199: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:48:33.614806: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:48:34.208185: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:48:34.209097: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:48:34.209714: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

[79]:
```
plt.title("MEM overall dataset")
plt.xlabel("n samples")
plt.ylabel("MEM_USAGE")
plt.plot(range(len(history_mem_usage)),history_mem_usage, label="history")
```

```
plt.plot(range(len(history_mem_usage), len(history_mem_usage) +␣
 ↪len(prediction_mem_usage)),original_mem_usage, label="actual", color="green")
plt.plot(range(len(history_mem_usage), len(history_mem_usage) +␣
 ↪len(prediction_mem_usage)),prediction_mem_usage, label="forecast",␣
 ↪color="orange")

plt.legend()
plt.show()

x = range(len(prediction_mem_usage))
plt.title("MEM USAGE prediction over actual")
plt.xlabel("n_samples")
plt.ylabel("MEM_USAGE")
plt.plot(x,original_mem_usage, label="actual", color="green")
plt.plot(x,prediction_mem_usage, label="forecast", color="orange")
plt.legend()
```



[79]: <matplotlib.legend.Legend at 0x7fea40b0c790>



[80]:
```
my_mean_absolute_percentage_error(original_mem_usage, prediction_mem_usage)
```

[80]: 89.30248583135541

4 SINGLE FEATURE TEMP

[81]:
```
x_train_multi, y_train_multi = multivariate_data(scaled_df, scaled_df[:, 2], 0,
                                                 training_size,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
x_val_multi, y_val_multi = multivariate_data(scaled_df, scaled_df[:, 2],
                                             training_size, None,␣
 ↪PAST_WINDOW_SIZE,
                                                 FUTURE_WINDOW_SIZE, STEP)
BATCH_SIZE = 128

train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
```

```
train_data_multi = train_data_multi.cache().shuffle(BUFFER_SIZE).
 ↪batch(BATCH_SIZE).repeat()

val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE).repeat()

multi_step_model = tf.keras.models.Sequential()
multi_step_model.add(tf.keras.layers.LSTM(32,
                                          return_sequences=True,
                                          input_shape=x_train_multi.shape[-2:]))
multi_step_model.add(tf.keras.layers.LSTM(16, activation='relu'))
multi_step_model.add(tf.keras.layers.Dense(FUTURE_WINDOW_SIZE))

multi_step_model.compile(optimizer=tf.keras.optimizers.RMSprop(clipvalue=1.0),␣
 ↪loss='mae')
print(multi_step_model.summary())

early_stopping = EarlyStopping(monitor='val_loss', patience = 3,␣
 ↪restore_best_weights=True)
multi_step_history = multi_step_model.fit(train_data_multi,
                                          epochs=EPOCHS,
                                          steps_per_epoch=EVALUATION_INTERVAL,
                                          validation_data=val_data_multi,
                                          validation_steps=EVALUATION_INTERVAL,
                                          callbacks=[early_stopping])
```

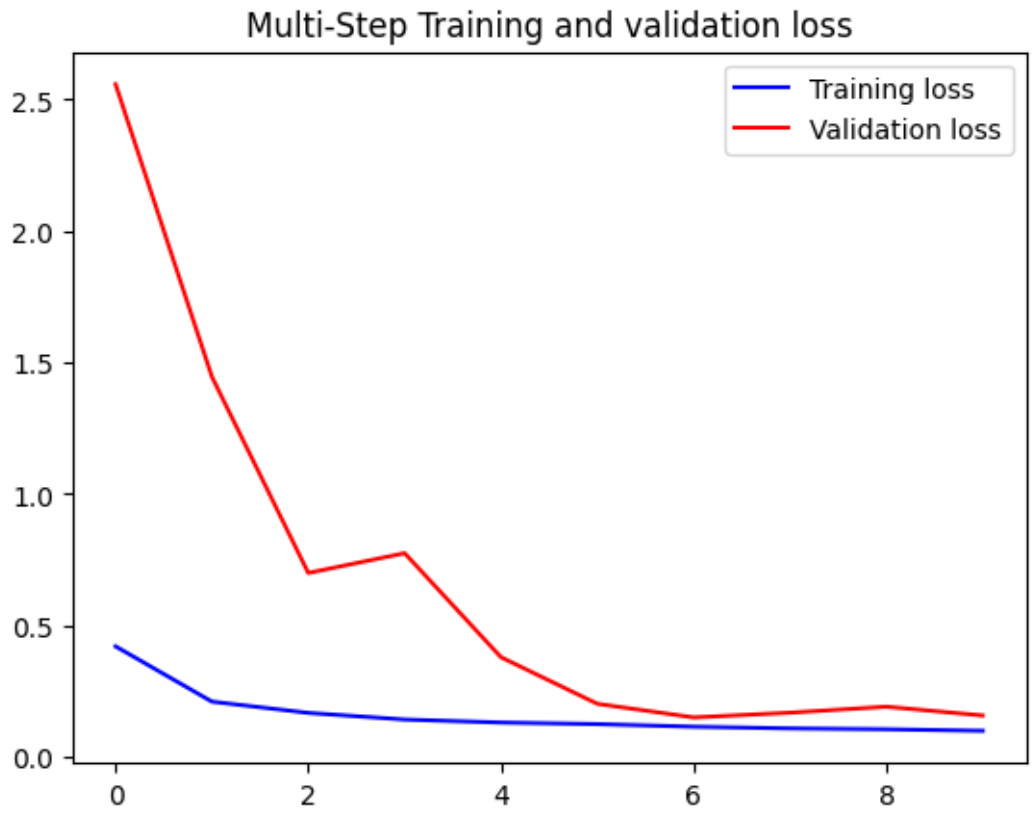
```
WARNING:tensorflow:Layer lstm_9 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 lstm_8 (LSTM)               (None, 48, 32)            4608

 lstm_9 (LSTM)               (None, 16)                3136

 dense_4 (Dense)             (None, 12)                204

=================================================================
Total params: 7,948
Trainable params: 7,948
Non-trainable params: 0
_________________________________________________________________
None
Epoch 1/10
2023-05-29 17:49:47.224487: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
```

```
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:49:47.225402: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:49:47.225956: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:49:47.294492: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_0' with dtype double and shape [2842,48,3]
         [[{{node Placeholder/_0}}]]
2023-05-29 17:49:47.400705: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:49:47.401454: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:49:47.402127: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
2023-05-29 17:49:48.122874: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:49:48.123827: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
```

```
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:49:48.124537: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

199/200 [============================>.] - ETA: 0s - loss: 0.4199

2023-05-29 17:49:53.463364: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:49:53.566276: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:49:53.567025: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:49:53.567700: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]

200/200 [==============================] - 9s 36ms/step - loss: 0.4199 -
val_loss: 2.5579
Epoch 2/10
200/200 [==============================] - 5s 26ms/step - loss: 0.2097 -
val_loss: 1.4451
Epoch 3/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1669 -
val_loss: 0.6991
Epoch 4/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1417 -
val_loss: 0.7743
Epoch 5/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1302 -
```

```
val_loss: 0.3786
Epoch 6/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1243 -
val_loss: 0.2014
Epoch 7/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1143 -
val_loss: 0.1497
Epoch 8/10
200/200 [==============================] - 5s 26ms/step - loss: 0.1079 -
val_loss: 0.1677
Epoch 9/10
200/200 [==============================] - 6s 29ms/step - loss: 0.1046 -
val_loss: 0.1904
Epoch 10/10
200/200 [==============================] - 5s 26ms/step - loss: 0.0988 -
val_loss: 0.1570
```

[82]:
```
plot_train_history(multi_step_history, 'Multi-Step Training and validation␣
↪loss')
```



[83]:
```
multi_step_model.save('best_multistep_multivariate_to_single_temp.h5')
```

[84]:
```
from tensorflow import keras
multi_step_model = keras.models.load_model("./
 ↪best_multistep_multivariate_to_single_temp.h5")
```

```
WARNING:tensorflow:Layer lstm_9 will not use cuDNN kernels since it doesn't meet
the criteria. It will use a generic GPU kernel as fallback when running on GPU.

2023-05-29 17:50:54.839812: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_2_grad/concat/split_2/split_dim' with
dtype int32
         [[{{node gradients/split_2_grad/concat/split_2/split_dim}}]]
2023-05-29 17:50:54.840697: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_grad/concat/split/split_dim' with dtype
int32
         [[{{node gradients/split_grad/concat/split/split_dim}}]]
2023-05-29 17:50:54.841267: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'gradients/split_1_grad/concat/split_1/split_dim' with
dtype int32
         [[{{node gradients/split_1_grad/concat/split_1/split_dim}}]]
```

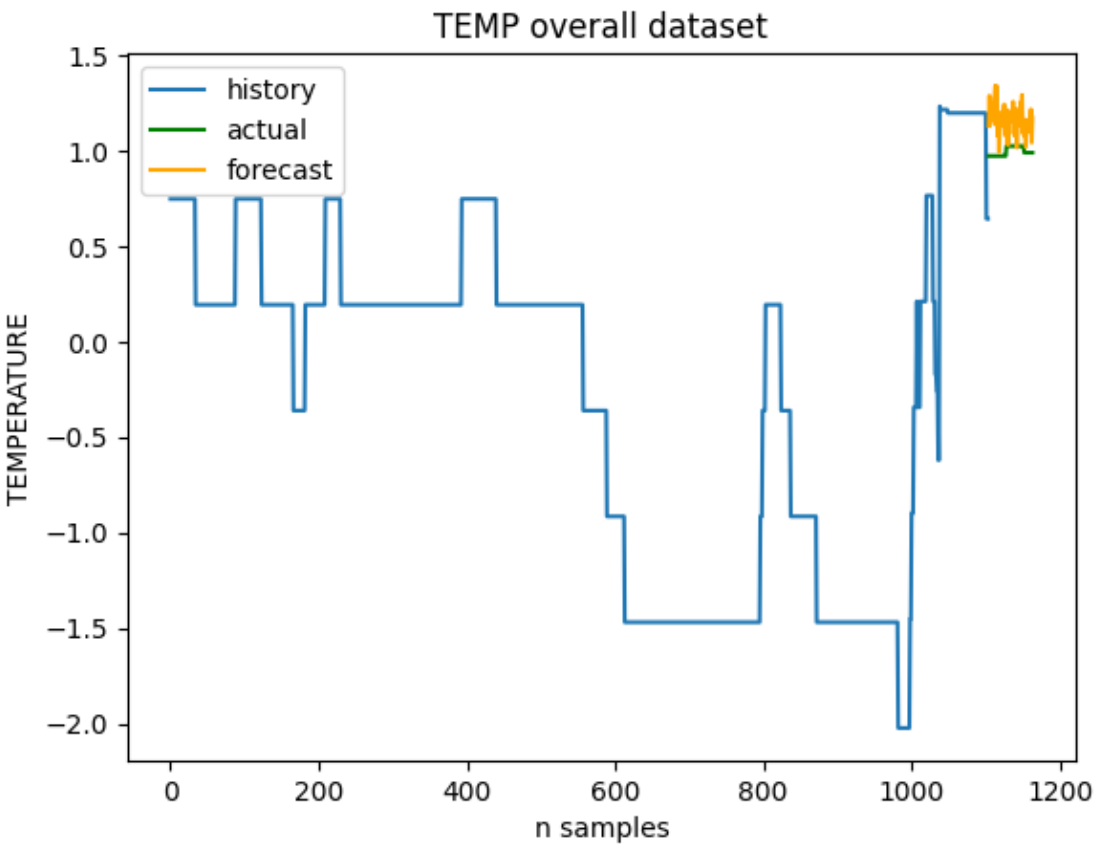
[ ]:
```
for x, y in val_data_multi.take(3):
    multi_step_plot(x[0], y[0], multi_step_model.predict(x)[0])
```

[86]:
```
import tensorflow as tf
train_data_multi = tf.data.Dataset.from_tensor_slices((x_train_multi,␣
 ↪y_train_multi))
train_data_multi = train_data_multi.cache().batch(BATCH_SIZE)
val_data_multi = tf.data.Dataset.from_tensor_slices((x_val_multi, y_val_multi))
val_data_multi = val_data_multi.batch(BATCH_SIZE)

predicted_temps = []
original_temps = []
history_temps = []


for x, y in train_data_multi:
    hx_temp = np.squeeze(x[0])[:,2]
    history_temps.append(hx_temp)

for x, y in val_data_multi:
    prediction = multi_step_model.predict(x, verbose = 0)[0]
    ori_mems = np.squeeze(y[0])
```

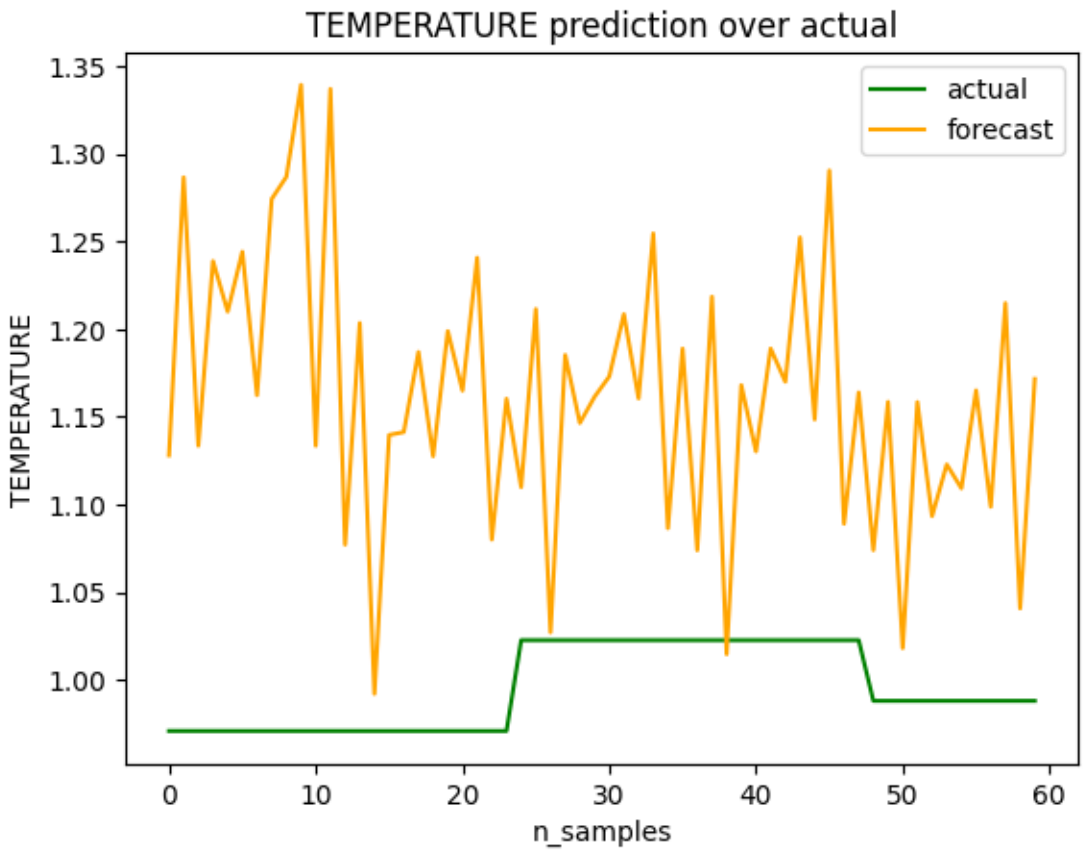
```
    predicted_temps.append(prediction)
    original_temps.append(ori_mems)


predicted_temp_usage = np.concatenate(predicted_temps, axis=0)
original_temp_usage = np.concatenate(original_temps, axis=0)
history_temp_usage = np.concatenate(history_temps, axis=0)
```

```
2023-05-29 17:53:31.102168: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [2842,12]
         [[{{node Placeholder/_1}}]]
2023-05-29 17:53:31.122024: I tensorflow/core/common_runtime/executor.cc:1197]
[/device:CPU:0] (DEBUG INFO) Executor start aborting (this does not indicate an
error and you can ignore this message): INVALID_ARGUMENT: You must feed a value
for placeholder tensor 'Placeholder/_1' with dtype double and shape [591,12]
         [[{{node Placeholder/_1}}]]
```

[87]:
```
plt.title("TEMP overall dataset")
plt.xlabel("n samples")
plt.ylabel("TEMPERATURE")
plt.plot(range(len(history_temp_usage)),history_temp_usage, label="history")
plt.plot(range(len(history_temp_usage), len(history_temp_usage) +␣
 ↪len(predicted_temp_usage)),original_temp_usage, label="actual",␣
 ↪color="green")
plt.plot(range(len(history_temp_usage), len(history_temp_usage) +␣
 ↪len(predicted_temp_usage)),predicted_temp_usage, label="forecast",␣
 ↪color="orange")

plt.legend()
plt.show()

x = range(len(predicted_temp_usage))
plt.title("TEMPERATURE prediction over actual")
plt.xlabel("n_samples")
plt.ylabel("TEMPERATURE")
plt.plot(x,original_temp_usage, label="actual", color="green")
plt.plot(x,predicted_temp_usage, label="forecast", color="orange")
plt.legend()
```



[87]: <matplotlib.legend.Legend at 0x7feaf000e890>



[88]:
```
my_mean_absolute_percentage_error(original_temp_usage, predicted_temp_usage)
```

[88]: 16.918544032771578

Overall the only metrics which reaches a reasonable accuracy is the temperature with 83% of accuracy (1-MAPE)