assignment-3-timeseries

November 5, 2023

[3]:
```
import os
fname = os.path.join("jena_climate_2009_2016.csv")

with open(fname) as f: data =
    f.read()

lines = data.split("\n") header =
lines[0].split(",") lines = lines[1:]
print(header) print(len(lines))
```

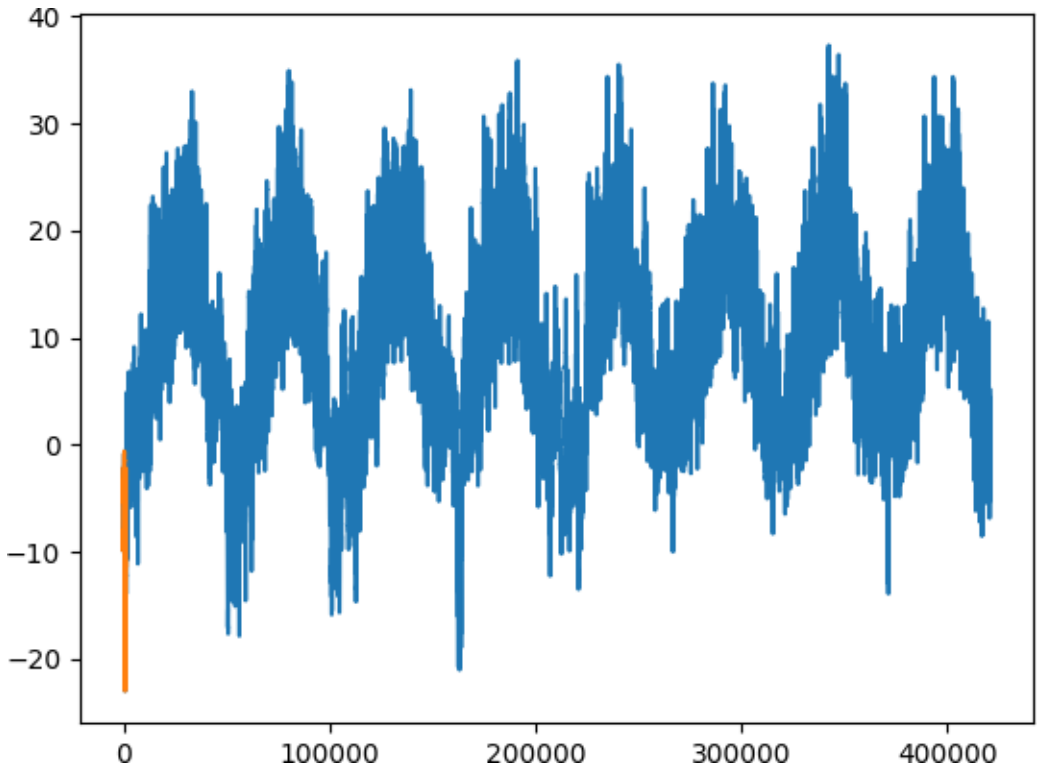
```
['"Date Time"', '"p (mbar)"', '"T (degC)"', '"Tpot (K)"', '"Tdew (degC)"','"rh
( %)"', '"VPmax (mbar)"', '"VPact (mbar)"', '"VPdef (mbar)"', '"sh (g/kg)"',
'"H2OC (mmol/mol)"', '"rho (g/m**3)"', '"wv (m/s)"', '"max. wv (m/s)"','"wd (deg)"']
420451
```

[4]:
```
import numpy as np
temperature = np.zeros((len(lines),))
raw_data = np.zeros((len(lines), len(header) - 1))
for i, line in enumerate(lines):
    values = [float(x) for x inline.split(",")[1:]] temperature[i] =
    values[1]
    raw_data[i, :] =values[:]
```

[5]:
```
#Plotting the temperature timeseries

from matplotlib import pyplot as plt
plt.plot(range(len(temperature)), temperature)
#Plotting the first 10 days of the temperature timeseries

plt.plot(range(1440), temperature[:1440])
#Computing the number of samples we'll use for each data split

num_trainsamples = int(0.5 *len(raw_data))
num_valsamples = int(0.25 * len(raw_data))
num_testsamples = len(raw_data) - num_trainsamples - num_valsamples
```

```
print("num_trainsamples:",num_trainsamples)
print("num_valsamples:", num_valsamples)
print("num_testsamples:", num_testsamples) #Preparing
the data
#Normalizing the data

mean =raw_data[:num_train_samples].mean(axis=0)
raw_data -= mean
std =raw_data[:num_train_samples].std(axis=0) raw_data
/= std
import numpy as np
from tensorflow import keras
int_sequence = np.arange(10)
dummy_dataset =keras.utils.timeseries_dataset_from_array(
        data=int_sequence[:-3],
        targets=int_sequence[3:],
        sequence_length=3,
        batch_size=2)
```

num_trainsamples: 210225
num_valsamples: 105112
num_testsamples: 105114



[6]:
```
for inputs, targets in dummy_dataset:
    for i in range(inputs.shape[0]):
        print([int(x) for x in inputs[i]], int(targets[i]))
#Instantiating datasets for training, validation, and testing

sampling_rate = 6
sequence_length = 120
delay = sampling_rate * (sequence_length + 24 - 1) batch_size =
256

train_dataset =keras.utils.timeseries_dataset_from_array( raw_data[:-
    delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True, batch_size=batch_size,
    start_index=0,
    end_index=num_trainsamples)
```

```
[1, 2, 3] 4
[2, 3, 4] 5
[3, 4, 5] 6
[4, 5, 6] 7
```

[7]:
```
val_dataset =keras.utils.timeseries_dataset_from_array( raw_data[:-
    delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True, batch_size=batch_size,
    start_index=num_trainsamples,
    end_index=num_trainsamples + num_valsamples)
```

[8]:
```
test_dataset =keras.utils.timeseries_dataset_from_array( raw_data[:-
    delay],
    targets=temperature[delay:],
    sampling_rate=sampling_rate,
    sequence_length=sequence_length,
    shuffle=True, batch_size=batch_size,
    start_index=num_train_samples + num_val_samples)
#Inspecting the output of one of our datasets

for samples, targets in train_dataset:
```

```
    print("samples shape:", samples.shape)
    print("targets shape:",targets.shape) break
#A common-sense, non-machine-learning baseline
#Computing the common-sense baseline MAE
```

samples shape: (256, 120, 14)
targets shape: (256,)

[9]:
```
def evaluate_naive_method(dataset): total_abs_err = 0.
    samples_seen = 0
    for samples, targets in dataset:
        preds = samples[:, -1, 1] * std[1] + mean[1] total_abs_err +=
        np.sum(np.abs(preds -targets)) samples_seen +=
        samples.shape[0]
    return total_abs_err / samples_seen

print(f"Validation MAE:{evaluate_naive_method(val_dataset):.2f}") print(f"Test
MAE: {evaluate_naive_method(test_dataset):.2f}") #Let's try a basic machine-
learning model
#Training and evaluating a densely connected model

from tensorflow import keras
from tensorflow.keras import layers

inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.Flatten()(inputs)
x = layers.Dense(16,activation="relu")(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)
```

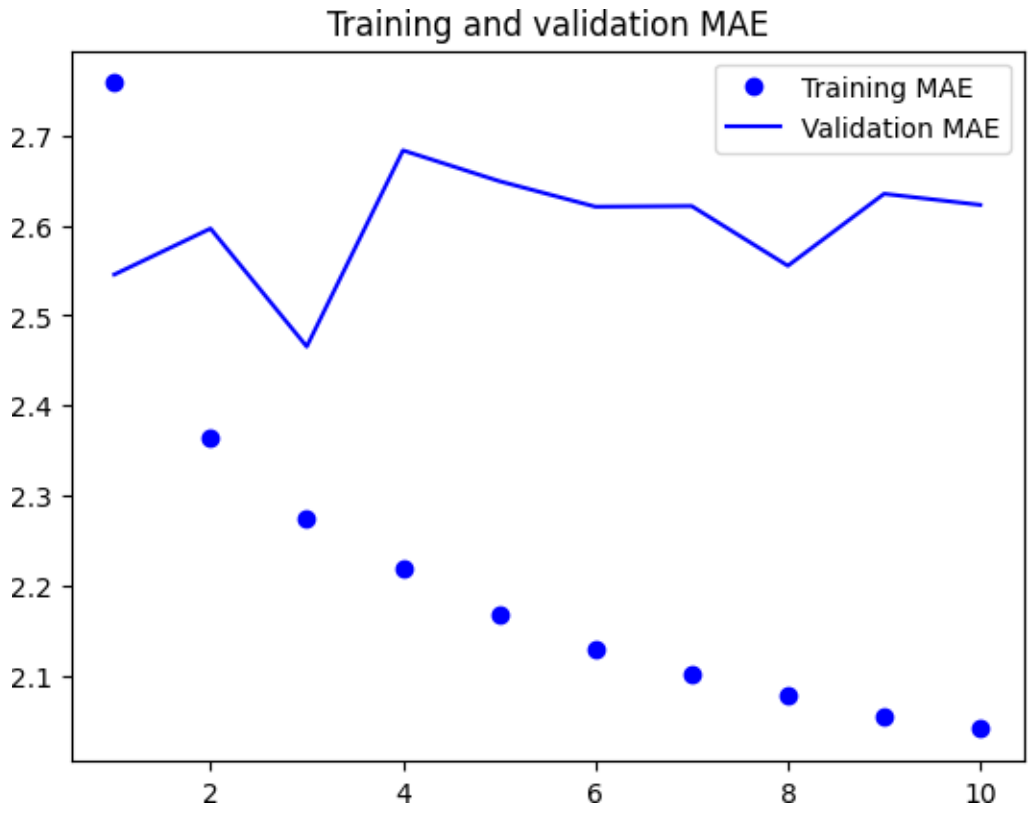
Test MAE: 2.62

[21]:
```
callbacks = [
    keras.callbacks.ModelCheckpoint("jena_dense.x",
                                    save_best_only=True)
]

model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =

model.fit(train_dataset,
                    epochs=10, validation_data=val_dataset,
                    callbacks=callbacks)
```

```
model = keras.models.load_model("jena_dense.x") print(f"Test MAE:
{model.evaluate(test_dataset)[1]:.2f}") #Plotting results

import matplotlib.pyplot as plt
loss = history.history["mae"] val_loss =
history.history["val_mae"] epochs = range(1,
len(loss) + 1) plt.figure()
plt.plot(epochs, loss, "bo", label="Training MAE") plt.plot(epochs,
val_loss, "b", label="Validation MAE") plt.title("Training and validation
MAE")
plt.legend() plt.show()
```

```
Epoch 1/10
819/819 [==============================] - 42s 45ms/step - loss: 12.6819 - mae:
2.7586 - val_loss: 10.5496 - val_mae: 2.5456
Epoch 2/10
819/819 [==============================] - 45s 54ms/step - loss: 9.0460 - mae:
2.3645 - val_loss: 10.9687 - val_mae: 2.5967 Epoch 3/10
819/819 [==============================] - 37s
                                          44ms/step - loss: 8.3278 - mae:
2.2737 - val_loss: 9.9327 - val_mae: 2.4655 Epoch 4/10
819/819 [==============================] - 36s
                                          43ms/step - loss: 7.9164 - mae:
2.2182 - val_loss: 11.5151 - val_mae: 2.6836 Epoch 5/10
819/819 [==============================] - 36s
                                          43ms/step - loss: 7.5438 - mae:
2.1666 - val_loss: 11.3356 - val_mae: 2.6495 Epoch 6/10
819/819 [==============================] - 45s
                                          54ms/step - loss: 7.2794 - mae:
2.1286 - val_loss: 11.1236 - val_mae: 2.6210 Epoch 7/10
819/819 [==============================] - 45s
                                          55ms/step - loss: 7.1022 - mae:
2.1023 - val_loss: 11.0057 - val_mae: 2.6218 Epoch 8/10
819/819 [==============================] - 46s
                                          56ms/step - loss: 6.9184 - mae:
2.0770 - val_loss: 10.4924 - val_mae: 2.5553 Epoch 9/10
819/819 [==============================] - 36s
                                          43ms/step - loss: 6.7709 - mae:
2.0544 - val_loss: 11.2613 - val_mae: 2.6354 Epoch
10/10
819/819 [==============================] - 35s 43ms/step - loss: 6.6655 - mae:
2.0404 - val_loss: 11.0213 - val_mae: 2.6230
405/405 [==============================] - 12s 29ms/step - loss: 11.5157 - mae:
2.6669
```

Test MAE: 2.67



[22]:

```
#Let's try a 1D convolutional model
inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.Conv1D(8, 24, activation="relu")(inputs)
x =layers.MaxPooling1D(2)(x)
x = layers.Conv1D(8, 12,activation="relu")(x) x =
layers.MaxPooling1D(2)(x)
x = layers.Conv1D(8, 6,activation="relu")(x) x =
layers.GlobalAveragePooling1D()(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
        keras.callbacks.ModelCheckpoint("jena_conv.x",
                                                save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                                epochs=10, validation_data=val_dataset,
```

```
                                callbacks=callbacks)

model = keras.models.load_model("jena_conv.x") print(f"Test MAE:
{model.evaluate(test_dataset)[1]:.2f}") #A first recurrent baseline
#A simple LSTM-based model
```

```
Epoch 1/10
819/819 [==============================] - 44s      47ms/step      - loss:  25.5503   - mae:
3.8901 - val_loss: 16.7556 - val_mae: 3.2061
Epoch 2/10
819/819 [==============================] - 47s      57ms/step      - loss:  15.6316   - mae:
3.1464 - val_loss: 14.6312 - val_mae: 3.0231
Epoch 3/10
819/819 [==============================] - 47s      57ms/step      - loss:  14.4119   - mae:
3.0170 - val_loss: 15.4460 - val_mae: 3.0568
Epoch 4/10
819/819 [==============================] - 46s      56ms/step      - loss:  13.5907   - mae:
2.9295 - val_loss: 14.7180 - val_mae: 3.0250
Epoch 5/10
819/819 [==============================] - 47s      56ms/step      - loss:  13.0013   - mae:
2.8626 - val_loss: 16.0589 - val_mae: 3.1335
Epoch 6/10
819/819 [==============================] - 46s      56ms/step      - loss:  12.4816   - mae:
2.8019 - val_loss: 15.6807 - val_mae: 3.1524
Epoch 7/10
819/819 [==============================] - 46s      56ms/step      - loss:  11.9862   - mae:
2.7462 - val_loss: 14.3125 - val_mae: 2.9955
Epoch 8/10
819/819 [==============================] - 37s      45ms/step      - loss:  11.5733   - mae:
2.6979 - val_loss: 14.7644 - val_mae: 3.0518
Epoch 9/10
819/819 [==============================] - 37s      45ms/step      - loss:  11.2338   - mae:
2.6597 - val_loss: 14.1816 - val_mae: 2.9709
Epoch 10/10
819/819 [==============================] - 46s      57ms/step      - loss:  10.9339   - mae:
2.6245 - val_loss: 13.7388 - val_mae: 2.9021
405/405 [==============================] - 12s      29ms/step      - loss:  15.2113   - mae:
3.0743
Test MAE: 3.07
```

[23]:
```
inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.LSTM(16)(inputs)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
```

```
    keras.callbacks.ModelCheckpoint("jena_lstm.x",
                                    save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                    epochs=10, validation_data=val_dataset,
                    callbacks=callbacks)

model = keras.models.load_model("jena_lstm.x") print(f"Test MAE:
{model.evaluate(test_dataset)[1]:.2f}")
```

```
Epoch 1/10
819/819 [==============================] - 46s 53ms/step - loss: 38.4776 -mae:
4.4817 - val_loss: 12.0231 - val_mae: 2.6628 Epoch 2/10
819/819 [==============================] - 42s 51ms/step - loss: 10.7663 -mae:
2.5549 - val_loss: 9.6746 - val_mae: 2.4277 Epoch 3/10
819/819 [==============================] -  39s  48ms/step  -  loss:  9.7750  -  mae:
2.4401 - val_loss: 9.7320 - val_mae:2.4316 Epoch 4/10
819/819 [==============================] -
                                          42s  51ms/step  -  loss:  9.3950  -  mae:
2.3901 - val_loss: 9.4856 - val_mae:2.3948 Epoch 5/10
819/819 [==============================] -
                                          42s  51ms/step  - loss:  9.1774  - mae:
2.3597 - val_loss: 9.3429 - val_mae:2.3838 Epoch 6/10
819/819 [==============================] -
                                          48s  59ms/step  - loss:  8.9676  - mae:
2.3327 - val_loss: 9.5073 - val_mae:2.4058 Epoch 7/10
819/819 [==============================] -
                                          39s  48ms/step  - loss:  8.7199  - mae:
2.3012 - val_loss: 9.4993 - val_mae:2.3971 Epoch 8/10
819/819 [==============================] -
                                          39s  47ms/step  - loss:  8.4484  - mae:
2.2723 - val_loss: 9.7170 - val_mae:2.4274 Epoch 9/10
819/819 [==============================] -
                                          39s  48ms/step  - loss:  8.1987  - mae:
2.2433 - val_loss: 9.7190 - val_mae:2.4298 Epoch
10/10
819/819 [==============================] -  49s  59ms/step  - loss:  8.0326  - mae:
2.2203 - val_loss: 9.8624 - val_mae:2.4422
405/405 [==============================] -  13s  30ms/step  -  loss:  10.8332 - mae:
2.5893
Test MAE: 2.59
```

[11]:
```
#Understanding recurrent neural networks #NumPy
implementation of a simple RNN

import numpy as np
timesteps = 100
input_features = 32
output_features = 64
inputs = np.random.random((timesteps,input_features)) state_t =
np.zeros((output_features,))
W = np.random.random((output_features, input_features)) U =
np.random.random((output_features,output_features)) b =
np.random.random((output_features,)) successive_outputs = []
for input_t in inputs:
        output_t = np.tanh(np.dot(W, input_t) + np.dot(U, state_t) +b)
        successive_outputs.append(output_t)
        state_t = output_t
final_output_sequence = np.stack(successive_outputs, axis=0)
#A recurrent layer in Keras
#An RNN layer that can process sequences of any length

num_features = 14
inputs = keras.Input(shape=(None,num_features)) outputs =
layers.SimpleRNN(16)(inputs)
#An RNN layer that returns only its last output step

num_features = 14
steps = 120
inputs = keras.Input(shape=(steps, num_features))
outputs = layers.SimpleRNN(16,return_sequences=False)(inputs)
print(outputs.shape)
#An RNN layer that returns its full output sequence

num_features = 14
steps = 120
inputs = keras.Input(shape=(steps, num_features))
outputs = layers.SimpleRNN(16,return_sequences=True)(inputs)
print(outputs.shape)
```

```
(None, 16)
(None, 120, 16)
```

[21]:
```
#Stacking RNN layers

inputs = keras.Input(shape=(steps, num_features))

x = layers.SimpleRNN(16, return_sequences=True)(inputs)
```

```
x = layers.SimpleRNN(16,return_sequences=True)(x) outputs =
layers.SimpleRNN(16)(x)


#Advanced use of recurrent neural networks #Using
recurrent dropout to fightoverfitting
#Training and evaluating a dropout-regularizedLSTM

inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.LSTM(32, recurrent_dropout=0.25)(inputs)
x = layers.Dropout(0.5)(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
      keras.callbacks.ModelCheckpoint("jena_lstm_dropout.x",
                                                  save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                              epochs=10,
                              validation_data=val_dataset,
                              callbacks=callbacks)
inputs = keras.Input(shape=(sequence_length, num_features))
x = layers.LSTM(32, recurrent_dropout=0.2, unroll=True)(inputs)


model = keras.models.load_model("jena_lstm_dropout.x") print(f"Test
MAE:{model.evaluate(test_dataset)[1]:.2f}")

Epoch 1/10
819/819 [==============================] - 226s 271ms/step - loss: 28.1520 -
mae: 3.9121 - val_loss: 9.9103 - val_mae: 2.4558 Epoch 2/10
819/819 [==============================] - 222s 270ms/step - loss: 14.9235 -
mae: 2.9963 - val_loss: 9.6143 - val_mae: 2.4181 Epoch 3/10
819/819 [==============================] - 212s 258ms/step - loss: 14.1405 -
mae: 2.9153 - val_loss: 9.3680 - val_mae: 2.3822 Epoch 4/10
819/819 [==============================] - 221s 270ms/step - loss: 13.5309 -
mae: 2.8518 - val_loss: 9.4704 - val_mae: 2.4024 Epoch 5/10
819/819 [==============================] - 222s 271ms/step - loss: 12.9737 -
mae: 2.7967 - val_loss: 9.3286 - val_mae: 2.3797 Epoch 6/10
819/819 [==============================] - 206s 252ms/step - loss: 12.5460 -
```

```
mae: 2.7484 - val_loss: 9.6331 - val_mae: 2.4191 Epoch 7/10
819/819 [==============================] - 220s 269ms/step - loss: 12.1261 -
mae: 2.7030 - val_loss: 9.9823 - val_mae: 2.4754 Epoch 8/10
819/819 [==============================] - 220s 268ms/step - loss: 11.8438 -
mae: 2.6708 - val_loss: 10.4755 - val_mae: 2.5311 Epoch 9/10
819/819 [==============================] - 219s 268ms/step - loss: 11.5342 -
mae: 2.6358 - val_loss: 9.7626 - val_mae: 2.4340 Epoch 10/10
819/819 [==============================] - 207s 252ms/step - loss: 11.3518 -
mae: 2.6164 - val_loss: 9.7759 - val_mae: 2.4359
405/405 [==============================] - 31s 76ms/step - loss: 10.4423 -mae:
2.5561
Test MAE: 2.56
```

[20]:
```
inputs = keras.Input(shape=(steps, num_features))

x = layers.SimpleRNN(16,return_sequences=True)(inputs) x =
layers.SimpleRNN(32,return_sequences=True)(inputs) x =
layers.SimpleRNN(64, return_sequences=True)(x) outputs =
layers.SimpleRNN(32)(x)


#Advanced use of recurrent neural networks #Using
recurrent dropout to fightoverfitting
#Training and evaluating a dropout-regularizedLSTM

inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.LSTM(32, recurrent_dropout=0.25)(inputs)
x = layers.Dropout(0.5)(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
        keras.callbacks.ModelCheckpoint("jena_lstm_dropout.x",
                                                        save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                                epochs=10,
                                validation_data=val_dataset,
                                callbacks=callbacks)
inputs = keras.Input(shape=(sequence_length, num_features))
x = layers.LSTM(32, recurrent_dropout=0.2, unroll=True)(inputs)
```

```
model = keras.models.load_model("jena_lstm_dropout.x") print(f"Test
MAE:{model.evaluate(test_dataset)[1]:.2f}")
```

```
Epoch 1/10
819/819 [==============================]  - 242s  292ms/step  - loss:  26.5987  -
mae: 3.8138 - val_loss: 9.6742 -val_mae: Epoch 2/10  2.4236
819/819 [==============================]
                                          - 210s  256ms/step  - loss:  14.8023  -
mae: 2.9855 - val_loss: 9.5182 -val_mae: Epoch 3/10  2.3899
819/819 [==============================]
                                          - 218s  265ms/step  - loss:  13.9631  -
mae: 2.8994 - val_loss: 9.5322 -val_mae: Epoch 4/10  2.3878
819/819 [==============================]
                                          - 220s  268ms/step  - loss:  13.4451  -
mae: 2.8396 - val_loss: 9.2781 -val_mae: Epoch 5/10  2.3634
819/819 [==============================]
                                          - 227s  277ms/step  - loss:  12.9626  -
mae: 2.7940 - val_loss: 9.1165 -val_mae: Epoch 6/10  2.3322
819/819 [==============================]
                                          - 222s  271ms/step  - loss:  12.5805  -
mae: 2.7480 - val_loss: 9.3165 -val_mae: Epoch 7/10  2.3609
819/819 [==============================]
                                          - 221s  269ms/step  - loss:  12.1743  -
mae: 2.6994 - val_loss: 9.1958 -val_mae: Epoch 8/10  2.3563
819/819 [==============================]
                                          - 205s  250ms/step  - loss:  11.8461  -
mae: 2.6663 - val_loss: 9.4023 -val_mae: Epoch 9/10  2.3833
819/819 [==============================]
                                          - 219s  267ms/step  - loss:  11.5906  -
mae: 2.6353 - val_loss: 9.4737 -val_mae: Epoch       2.3877
10/10
819/819 [==============================]  - 224s  274ms/step  - loss:  11.4514  -
mae: 2.6207 - val_loss: 9.5836 -val_mae:             2.4056
405/405 [==============================]  - 31s 75ms/step -  loss: 11.1362 -  mae:
2.6531
Test MAE: 2.65
```

[19]:
```
inputs = keras.Input(shape=(steps, num_features))

x = layers.SimpleRNN(32,return_sequences=True)(inputs) x =
layers.SimpleRNN(64,return_sequences=True)(inputs) x =
layers.SimpleRNN(128, return_sequences=True)(x) outputs =
layers.SimpleRNN(16)(x)


#Advanced use of recurrent neural networks #Using
recurrent dropout to fightoverfitting
```

```
#Training and evaluating a dropout-regularizedLSTM

inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.LSTM(32, recurrent_dropout=0.25)(inputs)
x = layers.Dropout(0.5)(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
      keras.callbacks.ModelCheckpoint("jena_lstm_dropout.x",
                                                  save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                              epochs=10, validation_data=val_dataset,
                              callbacks=callbacks)
inputs = keras.Input(shape=(sequence_length, num_features))
x = layers.LSTM(32, recurrent_dropout=0.2, unroll=True)(inputs)

model = keras.models.load_model("jena_lstm_dropout.x") print(f"Test
MAE:{model.evaluate(test_dataset)[1]:.2f}")
```

```
Epoch 1/10
819/819 [==============================] - 213s 257ms/step          - loss:    28.4844   -
mae: 3.9259 - val_loss: 9.8972 - val_mae: 2.4402
Epoch 2/10
819/819 [==============================] - 221s 270ms/step          - loss:    14.6652   -
mae: 2.9741 - val_loss: 9.3593 - val_mae: 2.3783
Epoch 3/10
819/819 [==============================] - 208s 254ms/step          - loss:    13.7223   -
mae: 2.8756 - val_loss: 9.2596 - val_mae: 2.3591
Epoch 4/10
819/819 [==============================] - 220s 268ms/step          - loss:    13.1934   -
mae: 2.8217 - val_loss: 9.0957 - val_mae: 2.3438
Epoch 5/10
819/819 [==============================] - 203s 248ms/step          - loss:    12.7352   -
mae: 2.7741 - val_loss: 9.6205 - val_mae: 2.4145
Epoch 6/10
819/819 [==============================] - 207s 253ms/step          - loss:    12.3161   -
mae: 2.7294 - val_loss: 9.0796 - val_mae: 2.3353
Epoch 7/10
819/819 [==============================] - 217s 265ms/step          - loss:    12.0812   -
mae: 2.7002 - val_loss: 9.1631 - val_mae: 2.3445
Epoch 8/10
819/819 [==============================] - 218s 265ms/step          - loss:    11.7724   -
mae: 2.6683 - val_loss: 9.1822 - val_mae: 2.3506
```

```
Epoch 9/10
819/819 [==============================] - 207s 252ms/step - loss: 11.5380 -
mae: 2.6365 - val_loss: 9.1958 - val_mae: 2.3421 Epoch 10/10
819/819 [==============================] - 204s 249ms/step - loss: 11.3564 -
mae: 2.6194 - val_loss: 9.1996 - val_mae: 2.3662
405/405 [==============================] - 29s 71ms/step - loss: 10.6082 -mae:
2.5817
Test MAE: 2.58
```

[22]:

```
#Stacking recurrent layers
#Training and evaluating a dropout-regularized, stacked LSTM model

inputs = keras.Input(shape=(sequence_length, raw_data.shape[-1]))
x = layers.LSTM(32, recurrent_dropout=0.5,return_sequences=True)(inputs) x =
layers.LSTM(32, recurrent_dropout=0.5)(x)
x = layers.Dropout(0.5)(x) outputs =
layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
      keras.callbacks.ModelCheckpoint("jena_stacked_lstm_dropout.x",
                                                  save_best_only=True)
]
model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                              epochs=10, validation_data=val_dataset,
                              callbacks=callbacks)

model =keras.models.load_model("jena_stacked_lstm_dropout.x") print(f"Test
MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

```
819/819 [==============================] - 439s 529ms/step - loss: 26.3901 -
mae: 3.7784 - val_loss: 9.6481 - val_mae: 2.4068
Epoch 2/10
819/819 [==============================] - 435s 531ms/step - loss: 13.7972 -
mae: 2.8802 - val_loss: 9.1589 - val_mae: 2.3459
Epoch 3/10
819/819 [==============================] - 389s 475ms/step - loss: 12.5851 -
mae: 2.7552 - val_loss: 9.7995 - val_mae: 2.4398
Epoch 4/10
819/819 [==============================] - 428s 523ms/step - loss: 11.6999 -
mae: 2.6497 - val_loss: 10.0053 - val_mae: 2.4676
Epoch 5/10
819/819 [==============================] - 432s 528ms/step - loss: 10.8755 -
mae: 2.5532 - val_loss: 10.4926 - val_mae: 2.5181
```

```
Epoch 6/10
819/819 [==============================] - 428s 523ms/step - loss: 10.2783 -
mae: 2.4764 - val_loss: 10.7970 - val_mae: 2.5499
Epoch 7/10
819/819 [==============================] - 426s 520ms/step - loss: 9.7765 - mae:
2.4139 - val_loss: 11.4551 - val_mae: 2.6354 Epoch 8/10
819/819 [==============================] - 391s
                                    477ms/step - loss: 9.3526 - mae:
2.3613 - val_loss: 10.9944 - val_mae: 2.5935 Epoch 9/10
819/819 [==============================] - 429s
                                    524ms/step - loss: 8.9984 - mae:
2.3153 - val_loss: 11.1027 - val_mae: 2.6056 Epoch
10/10
819/819 [==============================] - 426s 520ms/step - loss: 8.6864 - mae:
2.2761 - val_loss: 11.3568 - val_mae: 2.6380
405/405 [==============================] - 47s 114ms/step - loss:10.4441 - mae:
2.5380
Test MAE: 2.54
```

[28]:

```
#Using bidirectional RNNs
#Training and evaluating a bidirectional LSTM

inputs = keras.Input(shape=(sequence_length,raw_data.shape[-1])) x =
layers.Bidirectional(layers.LSTM(32))(inputs)
outputs = layers.Dense(1)(x)
model = keras.Model(inputs, outputs)

callbacks = [
      keras.callbacks.ModelCheckpoint("jena_bidirectional_lstm.x",
                                                save_best_only=True)
]

model.compile(optimizer="rmsprop", loss="mse",metrics=["mae"]) history =
model.fit(train_dataset,
                              epochs=10, validation_data=val_dataset,
                              callbacks=callbacks)

model =keras.models.load_model("jena_bidirectional_lstm.x") print(f"Test
MAE: {model.evaluate(test_dataset)[1]:.2f}")
```

```
819/819 [==============================] - 224s 268ms/step - loss: 15.9157 -
mae: 2.9029 - val_loss: 9.8896 - val_mae: 2.4314 Epoch 2/10
819/819 [==============================] - 207s 253ms/step - loss: 7.8691 -mae:
2.1835 - val_loss: 10.4940 - val_mae: 2.5213 Epoch 3/10
```

819/819 [==============================] - 248s 302ms/step - loss: 6.7932 - mae: 2.0251 - val_loss: 10.6977 - val_mae: 2.5293 Epoch 4/10
819/819 [==============================] - 247s 301ms/step - loss: 5.9536 - mae: 1.8914 - val_loss: 11.5872 - val_mae: 2.6205 Epoch 5/10
819/819 [==============================] - 207s 253ms/step - loss: 5.3753 - mae: 1.7954 - val_loss: 11.4596 - val_mae: 2.6279 Epoch 6/10
819/819 [==============================] - 210s 256ms/step - loss: 4.9469 - mae: 1.7194 - val_loss: 11.6952 - val_mae: 2.6478 Epoch 7/10
819/819 [==============================] - 249s 304ms/step - loss: 4.5574 - mae: 1.6517 - val_loss: 12.1527 - val_mae: 2.7123 Epoch 8/10
819/819 [==============================] - 248s 302ms/step - loss: 4.2283 - mae: 1.5893 - val_loss: 12.2758 - val_mae: 2.7321 Epoch 9/10
819/819 [==============================] - 210s 256ms/step - loss: 3.9205 - mae: 1.5307 - val_loss: 12.9486 - val_mae: 2.7929 Epoch 10/10
819/819 [==============================] - 209s 255ms/step - loss: 3.7182 - mae: 1.4909 - val_loss: 12.9353 - val_mae: 2.7936
405/405 [==============================] - 46s 110ms/step - loss:10.5354 - mae: 2.5753
Test MAE: 2.58