assignment-04-notebook

September 8, 2024

1 Assignment 4 - TinyML HelloWorld - Section 1

Based on the **hello_world** example from TensorFlow Lite for MicroControllers.

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1.1 Introduction

In this section you will train a Tensorflow model to a set of sinusoidal data. First you will synthesize the data to mimic a sine wave. Then you can build your own tensorflow model and fit the model to the generated data. Start by importing the relevant modules.

1.2 Import modules

```
[1]: # Import Tensorflow and NumPy
     # Set random seed to get reproducible results
     import numpy as np
     np.random.seed(1)

     import tensorflow as tf
     tf.random.set_seed(1)
```

```
[2]: import os
     from tensorflow import keras
     import matplotlib.pyplot as plt
     import math
```

1.3 Create the Dataset

You can use NumPy to generate a sinewave data and add some gaussian noise to make the data more realistic. The dataset will consist of 1000 datapoints (x-values) and relevant y-values. The following code creates a sine wave dataset.

```
[3]: # Number of sample datapoints
     SAMPLES = 1000

     # Generate a uniformly distributed set of random numbers in the range from
     # 0 to 2, which covers a complete sine wave oscillation
     x_values = np.random.uniform(
```
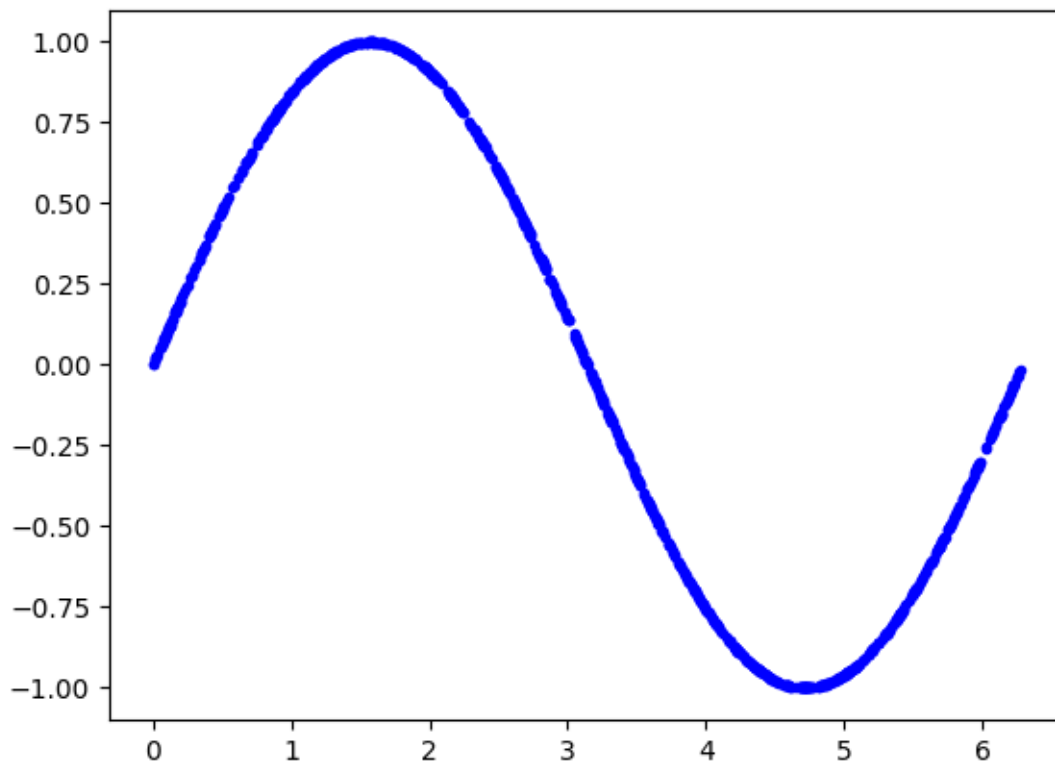
```
    low=0, high=2*math.pi, size=SAMPLES).astype(np.float32)

# Shuffle the values to guarantee they're not in order
np.random.shuffle(x_values)

# Calculate the corresponding sine values
y_values = np.sin(x_values).astype(np.float32)

# Plot the data. The 'b.' argument tells the library to print blue dots.
plt.plot(x_values, y_values, 'b.')
plt.show()
```
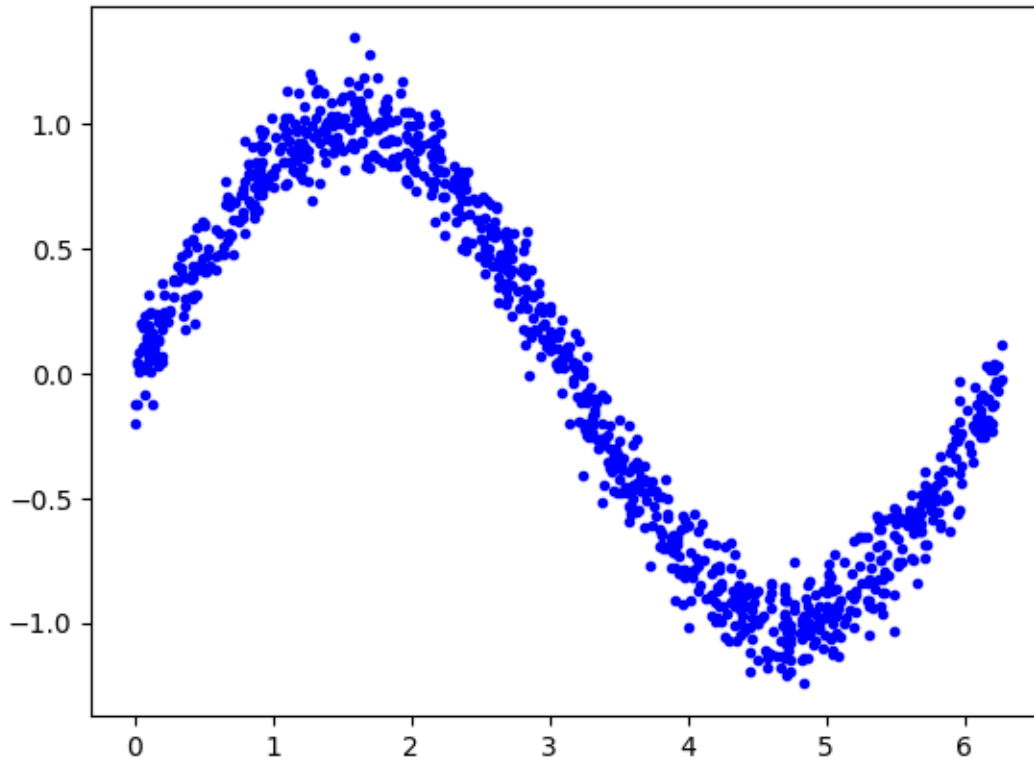

Next add noise to the data to make the data more realistic. (In real-life the data we obtain usually get contaminated by different kinds of noise.)

```
[4]: # Add a small random number to each y value
     y_values += 0.1 * np.random.randn(*y_values.shape)

     # Plot our data
     plt.plot(x_values, y_values, 'b.')
     plt.show()
```

1.4   Pre-process data (Graded)

The dataset has been given, now you will have to split this dataset into train, validation and test subsets. The following table shows the split ratio you should be using.

Split	Percentage
Train	60%
Validation	20%
Test	20%

You may use the `np.split()` function for obtaining 3 splits of data from one line of code. You have to provide the indiced of points which the dataset is divided. The second argument to `np.split()` is an array of indices where the data will be split. We provide two indices, so the data will be divided into three chunks. For more clarification look into the documentation of np.split().

1.4.1   Exercise 1

Complete the code below to split the data accordingly and plot all three splits in the same plot.

```
[5]: # Define the indices where the dataset will get chopped (TODO)
TRAIN_SPLIT = int(0.6 * SAMPLES)
```

```
TEST_SPLIT = int(0.8 * SAMPLES)

# Use np.split to chop the data into three parts (TODO)
x_train, x_validate, x_test = np.split(x_values, [TRAIN_SPLIT, TEST_SPLIT])
y_train, y_validate, y_test = np.split(y_values, [TRAIN_SPLIT, TEST_SPLIT])

# Double check that our splits add up correctly
assert (x_train.size + x_validate.size + x_test.size) ==  SAMPLES

# Plot the data in each partition in different colors
plt.plot(x_train, y_train, 'b.', label="Train")
plt.plot(x_test, y_test, 'r.', label="Test")
plt.plot(x_validate, y_validate, 'g.', label="Validate")
plt.legend()
plt.show()
```
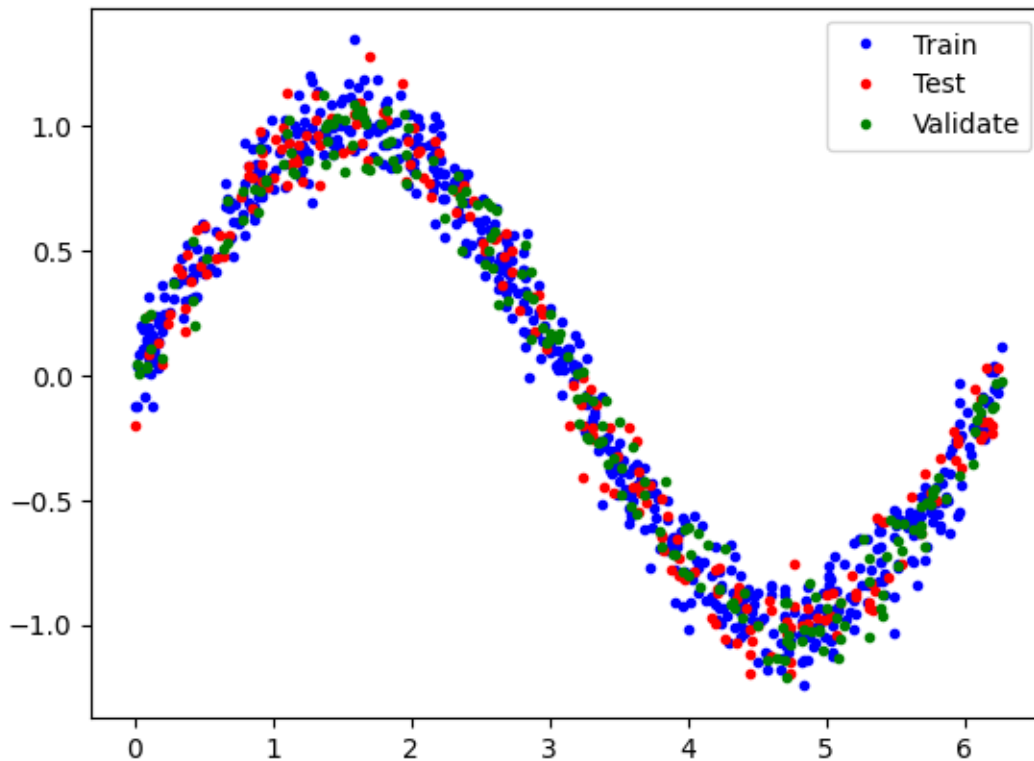

1.5   Build the Model (Graded)

You have successfully pre-processed the dataset. Next you will have to define build the Tensorflow model using Keras. You may use the Tensorflow Keras Sequential API. Please refer to the official Keras documentation for further information. Use the below architecture to design your the model.

- Input layer

4

- 2 Dense layers each consisting of 16 hidden units and ReLU activation - keras.layers.Dense()
- Output layer with 1 unit

1.5.1 Exercise 2

Design the sequential model according to the specifications above.

```python
[6]: # Define the model using the Keras Sequential API
model = keras.Sequential([
    # Input layer is implicitly defined by the shape of the first layer
    keras.layers.Dense(16, activation='relu', input_shape=(1,)),  # First Dense␣
↪layer with 16 units and ReLU
    keras.layers.Dense(16, activation='relu'),                     # Second␣
↪Dense layer with 16 units and ReLU
    keras.layers.Dense(1)                                          # Output␣
↪layer with 1 unit
])

# Display the model architecture
model.summary()
```

/usr/local/lib/python3.10/dist-packages/keras/src/layers/core/dense.py:87:
UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When
using Sequential models, prefer using an `Input(shape)` object as the first
layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)

Model: "sequential"

Layer (type)	Output Shape	␣
↪Param #		
dense (Dense)	(None, 16)	␣
↪ 32		
dense_1 (Dense)	(None, 16)	␣
↪272		
dense_2 (Dense)	(None, 1)	␣
↪ 17		

Total params: 321 (1.25 KB)

Trainable params: 321 (1.25 KB)

Non-trainable params: 0 (0.00 B)

Now that you have created the model, specify the optimizer, loss function and acuracy metrics. Use the below,

- Optimizer: Adam
- Loss function: Mean Squared Error (MSE)
- Metric: Mean Absolute Error (MAE)

You may use `model.compile()` and read the tf.keras.Sequential documentation for this.

1.5.2 Exercise 3

Set the optimizer and loss function details as specified as above.

```python
[7]: # Compile the model using a standard optimizer and loss function for regression
model.compile(
    optimizer='adam',                  # Optimizer: Adam
    loss='mean_squared_error',         # Loss function: Mean Squared Error (MSE)
    metrics=['mean_absolute_error']    # Metric: Mean Absolute Error (MAE)
)
```

```python
[8]: # Get model summary
model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 16)	32
dense_1 (Dense)	(None, 16)	272
dense_2 (Dense)	(None, 1)	17

Total params: 321 (1.25 KB)

Trainable params: 321 (1.25 KB)

```
Non-trainable params: 0 (0.00 B)
```

1.6 Train the Model (Graded)

Fit the model to the data using `model.fit()`. Train for 500 epochs with a batch size of 64. Use only the train and validation sets during training.

1.6.1 Exercise 4

Fit the model to the data. Keep track of the losses and metrics using `history` object.

```python
[9]: # Fit the model to the data and keep track of losses
history = model.fit(
    x_train,              # Training input data
    y_train,              # Training output data
    epochs=500,           # Number of epochs
    batch_size=64,        # Batch size
    validation_data=(x_validate, y_validate),  # Validation data
    verbose=1             # Verbose mode to display progress during training
)
```

```
Epoch 1/500
10/10                 1s 24ms/step -
loss: 0.4288 - mean_absolute_error: 0.5586 - val_loss: 0.3986 -
val_mean_absolute_error: 0.5323
Epoch 2/500
10/10                 0s 7ms/step - loss:
0.4052 - mean_absolute_error: 0.5418 - val_loss: 0.3806 -
val_mean_absolute_error: 0.5302
Epoch 3/500
10/10                 0s 6ms/step - loss:
0.3847 - mean_absolute_error: 0.5339 - val_loss: 0.3591 -
val_mean_absolute_error: 0.5122
Epoch 4/500
10/10                 0s 6ms/step - loss:
0.3633 - mean_absolute_error: 0.5142 - val_loss: 0.3387 -
val_mean_absolute_error: 0.4971
Epoch 5/500
10/10                 0s 7ms/step - loss:
0.3412 - mean_absolute_error: 0.4980 - val_loss: 0.3089 -
val_mean_absolute_error: 0.4786
Epoch 6/500
10/10                 0s 7ms/step - loss:
0.3120 - mean_absolute_error: 0.4794 - val_loss: 0.2872 -
val_mean_absolute_error: 0.4631
Epoch 7/500
10/10                 0s 6ms/step - loss:
0.2899 - mean_absolute_error: 0.4609 - val_loss: 0.2671 -
```

```
val_mean_absolute_error: 0.4465
Epoch 8/500
10/10            0s 6ms/step - loss:
0.2709 - mean_absolute_error: 0.4457 - val_loss: 0.2496 -
val_mean_absolute_error: 0.4341
Epoch 9/500
10/10            0s 8ms/step - loss:
0.2534 - mean_absolute_error: 0.4325 - val_loss: 0.2328 -
val_mean_absolute_error: 0.4196
Epoch 10/500
10/10            0s 6ms/step - loss:
0.2363 - mean_absolute_error: 0.4181 - val_loss: 0.2166 -
val_mean_absolute_error: 0.4054
Epoch 11/500
10/10            0s 5ms/step - loss:
0.2211 - mean_absolute_error: 0.4051 - val_loss: 0.2032 -
val_mean_absolute_error: 0.3940
Epoch 12/500
10/10            0s 6ms/step - loss:
0.2077 - mean_absolute_error: 0.3926 - val_loss: 0.1905 -
val_mean_absolute_error: 0.3820
Epoch 13/500
10/10            0s 6ms/step - loss:
0.1953 - mean_absolute_error: 0.3811 - val_loss: 0.1796 -
val_mean_absolute_error: 0.3710
Epoch 14/500
10/10            0s 5ms/step - loss:
0.1851 - mean_absolute_error: 0.3706 - val_loss: 0.1704 -
val_mean_absolute_error: 0.3608
Epoch 15/500
10/10            0s 7ms/step - loss:
0.1759 - mean_absolute_error: 0.3603 - val_loss: 0.1623 -
val_mean_absolute_error: 0.3510
Epoch 16/500
10/10            0s 6ms/step - loss:
0.1679 - mean_absolute_error: 0.3509 - val_loss: 0.1554 -
val_mean_absolute_error: 0.3418
Epoch 17/500
10/10            0s 5ms/step - loss:
0.1612 - mean_absolute_error: 0.3422 - val_loss: 0.1496 -
val_mean_absolute_error: 0.3334
Epoch 18/500
10/10            0s 8ms/step - loss:
0.1554 - mean_absolute_error: 0.3342 - val_loss: 0.1448 -
val_mean_absolute_error: 0.3258
Epoch 19/500
10/10            0s 5ms/step - loss:
0.1506 - mean_absolute_error: 0.3270 - val_loss: 0.1408 -
```

```
val_mean_absolute_error: 0.3188
Epoch 20/500
10/10              0s 5ms/step - loss:
0.1465 - mean_absolute_error: 0.3204 - val_loss: 0.1374 -
val_mean_absolute_error: 0.3126
Epoch 21/500
10/10              0s 5ms/step - loss:
0.1431 - mean_absolute_error: 0.3145 - val_loss: 0.1347 -
val_mean_absolute_error: 0.3071
Epoch 22/500
10/10              0s 6ms/step - loss:
0.1403 - mean_absolute_error: 0.3093 - val_loss: 0.1324 -
val_mean_absolute_error: 0.3022
Epoch 23/500
10/10              0s 7ms/step - loss:
0.1379 - mean_absolute_error: 0.3047 - val_loss: 0.1305 -
val_mean_absolute_error: 0.2978
Epoch 24/500
10/10              0s 5ms/step - loss:
0.1360 - mean_absolute_error: 0.3007 - val_loss: 0.1289 -
val_mean_absolute_error: 0.2939
Epoch 25/500
10/10              0s 6ms/step - loss:
0.1342 - mean_absolute_error: 0.2971 - val_loss: 0.1276 -
val_mean_absolute_error: 0.2905
Epoch 26/500
10/10              0s 5ms/step - loss:
0.1328 - mean_absolute_error: 0.2940 - val_loss: 0.1264 -
val_mean_absolute_error: 0.2874
Epoch 27/500
10/10              0s 7ms/step - loss:
0.1315 - mean_absolute_error: 0.2911 - val_loss: 0.1255 -
val_mean_absolute_error: 0.2848
Epoch 28/500
10/10              0s 8ms/step - loss:
0.1304 - mean_absolute_error: 0.2885 - val_loss: 0.1247 -
val_mean_absolute_error: 0.2825
Epoch 29/500
10/10              0s 5ms/step - loss:
0.1295 - mean_absolute_error: 0.2863 - val_loss: 0.1240 -
val_mean_absolute_error: 0.2806
Epoch 30/500
10/10              0s 5ms/step - loss:
0.1287 - mean_absolute_error: 0.2843 - val_loss: 0.1233 -
val_mean_absolute_error: 0.2788
Epoch 31/500
10/10              0s 5ms/step - loss:
0.1279 - mean_absolute_error: 0.2824 - val_loss: 0.1227 -
```

```
val_mean_absolute_error: 0.2772
Epoch 32/500
10/10          0s 5ms/step - loss:
0.1273 - mean_absolute_error: 0.2808 - val_loss: 0.1222 -
val_mean_absolute_error: 0.2758
Epoch 33/500
10/10          0s 6ms/step - loss:
0.1266 - mean_absolute_error: 0.2793 - val_loss: 0.1217 -
val_mean_absolute_error: 0.2745
Epoch 34/500
10/10          0s 5ms/step - loss:
0.1261 - mean_absolute_error: 0.2780 - val_loss: 0.1212 -
val_mean_absolute_error: 0.2734
Epoch 35/500
10/10          0s 5ms/step - loss:
0.1255 - mean_absolute_error: 0.2766 - val_loss: 0.1208 -
val_mean_absolute_error: 0.2723
Epoch 36/500
10/10          0s 5ms/step - loss:
0.1249 - mean_absolute_error: 0.2754 - val_loss: 0.1203 -
val_mean_absolute_error: 0.2713
Epoch 37/500
10/10          0s 6ms/step - loss:
0.1244 - mean_absolute_error: 0.2743 - val_loss: 0.1199 -
val_mean_absolute_error: 0.2704
Epoch 38/500
10/10          0s 6ms/step - loss:
0.1239 - mean_absolute_error: 0.2733 - val_loss: 0.1194 -
val_mean_absolute_error: 0.2695
Epoch 39/500
10/10          0s 7ms/step - loss:
0.1234 - mean_absolute_error: 0.2723 - val_loss: 0.1190 -
val_mean_absolute_error: 0.2686
Epoch 40/500
10/10          0s 5ms/step - loss:
0.1229 - mean_absolute_error: 0.2713 - val_loss: 0.1185 -
val_mean_absolute_error: 0.2679
Epoch 41/500
10/10          0s 5ms/step - loss:
0.1224 - mean_absolute_error: 0.2705 - val_loss: 0.1181 -
val_mean_absolute_error: 0.2671
Epoch 42/500
10/10          0s 5ms/step - loss:
0.1219 - mean_absolute_error: 0.2696 - val_loss: 0.1176 -
val_mean_absolute_error: 0.2663
Epoch 43/500
10/10          0s 5ms/step - loss:
0.1215 - mean_absolute_error: 0.2688 - val_loss: 0.1172 -
```

val_mean_absolute_error: 0.2656
Epoch 44/500
10/10   0s 7ms/step - loss:
0.1210 - mean_absolute_error: 0.2681 - val_loss: 0.1168 -
val_mean_absolute_error: 0.2649
Epoch 45/500
10/10   0s 5ms/step - loss:
0.1205 - mean_absolute_error: 0.2673 - val_loss: 0.1163 -
val_mean_absolute_error: 0.2642
Epoch 46/500
10/10   0s 6ms/step - loss:
0.1200 - mean_absolute_error: 0.2665 - val_loss: 0.1159 -
val_mean_absolute_error: 0.2634
Epoch 47/500
10/10   0s 6ms/step - loss:
0.1195 - mean_absolute_error: 0.2657 - val_loss: 0.1154 -
val_mean_absolute_error: 0.2626
Epoch 48/500
10/10   0s 7ms/step - loss:
0.1190 - mean_absolute_error: 0.2649 - val_loss: 0.1150 -
val_mean_absolute_error: 0.2619
Epoch 49/500
10/10   0s 5ms/step - loss:
0.1185 - mean_absolute_error: 0.2642 - val_loss: 0.1145 -
val_mean_absolute_error: 0.2612
Epoch 50/500
10/10   0s 5ms/step - loss:
0.1180 - mean_absolute_error: 0.2635 - val_loss: 0.1141 -
val_mean_absolute_error: 0.2604
Epoch 51/500
10/10   0s 5ms/step - loss:
0.1175 - mean_absolute_error: 0.2628 - val_loss: 0.1136 -
val_mean_absolute_error: 0.2596
Epoch 52/500
10/10   0s 6ms/step - loss:
0.1170 - mean_absolute_error: 0.2620 - val_loss: 0.1131 -
val_mean_absolute_error: 0.2587
Epoch 53/500
10/10   0s 5ms/step - loss:
0.1165 - mean_absolute_error: 0.2612 - val_loss: 0.1126 -
val_mean_absolute_error: 0.2579
Epoch 54/500
10/10   0s 5ms/step - loss:
0.1159 - mean_absolute_error: 0.2604 - val_loss: 0.1121 -
val_mean_absolute_error: 0.2571
Epoch 55/500
10/10   0s 6ms/step - loss:
0.1154 - mean_absolute_error: 0.2597 - val_loss: 0.1117 -

```
val_mean_absolute_error: 0.2564
Epoch 56/500
10/10            0s 5ms/step - loss:
0.1149 - mean_absolute_error: 0.2589 - val_loss: 0.1112 -
val_mean_absolute_error: 0.2557
Epoch 57/500
10/10            0s 8ms/step - loss:
0.1144 - mean_absolute_error: 0.2581 - val_loss: 0.1107 -
val_mean_absolute_error: 0.2550
Epoch 58/500
10/10            0s 6ms/step - loss:
0.1139 - mean_absolute_error: 0.2574 - val_loss: 0.1102 -
val_mean_absolute_error: 0.2542
Epoch 59/500
10/10            0s 5ms/step - loss:
0.1133 - mean_absolute_error: 0.2566 - val_loss: 0.1097 -
val_mean_absolute_error: 0.2535
Epoch 60/500
10/10            0s 5ms/step - loss:
0.1128 - mean_absolute_error: 0.2558 - val_loss: 0.1092 -
val_mean_absolute_error: 0.2527
Epoch 61/500
10/10            0s 5ms/step - loss:
0.1122 - mean_absolute_error: 0.2550 - val_loss: 0.1087 -
val_mean_absolute_error: 0.2519
Epoch 62/500
10/10            0s 9ms/step - loss:
0.1117 - mean_absolute_error: 0.2543 - val_loss: 0.1082 -
val_mean_absolute_error: 0.2511
Epoch 63/500
10/10            0s 9ms/step - loss:
0.1112 - mean_absolute_error: 0.2535 - val_loss: 0.1077 -
val_mean_absolute_error: 0.2504
Epoch 64/500
10/10            0s 8ms/step - loss:
0.1106 - mean_absolute_error: 0.2527 - val_loss: 0.1072 -
val_mean_absolute_error: 0.2495
Epoch 65/500
10/10            0s 9ms/step - loss:
0.1101 - mean_absolute_error: 0.2520 - val_loss: 0.1067 -
val_mean_absolute_error: 0.2487
Epoch 66/500
10/10            0s 9ms/step - loss:
0.1095 - mean_absolute_error: 0.2512 - val_loss: 0.1062 -
val_mean_absolute_error: 0.2479
Epoch 67/500
10/10            0s 8ms/step - loss:
0.1089 - mean_absolute_error: 0.2504 - val_loss: 0.1057 -
```

```
val_mean_absolute_error: 0.2472
Epoch 68/500
10/10          0s 8ms/step - loss:
0.1084 - mean_absolute_error: 0.2496 - val_loss: 0.1052 -
val_mean_absolute_error: 0.2464
Epoch 69/500
10/10          0s 8ms/step - loss:
0.1078 - mean_absolute_error: 0.2488 - val_loss: 0.1047 -
val_mean_absolute_error: 0.2456
Epoch 70/500
10/10          0s 8ms/step - loss:
0.1073 - mean_absolute_error: 0.2480 - val_loss: 0.1041 -
val_mean_absolute_error: 0.2448
Epoch 71/500
10/10          0s 10ms/step -
loss: 0.1067 - mean_absolute_error: 0.2472 - val_loss: 0.1036 -
val_mean_absolute_error: 0.2440
Epoch 72/500
10/10          0s 11ms/step -
loss: 0.1061 - mean_absolute_error: 0.2464 - val_loss: 0.1031 -
val_mean_absolute_error: 0.2431
Epoch 73/500
10/10          0s 8ms/step - loss:
0.1055 - mean_absolute_error: 0.2455 - val_loss: 0.1026 -
val_mean_absolute_error: 0.2423
Epoch 74/500
10/10          0s 8ms/step - loss:
0.1050 - mean_absolute_error: 0.2447 - val_loss: 0.1020 -
val_mean_absolute_error: 0.2415
Epoch 75/500
10/10          0s 8ms/step - loss:
0.1044 - mean_absolute_error: 0.2439 - val_loss: 0.1015 -
val_mean_absolute_error: 0.2407
Epoch 76/500
10/10          0s 9ms/step - loss:
0.1038 - mean_absolute_error: 0.2430 - val_loss: 0.1010 -
val_mean_absolute_error: 0.2400
Epoch 77/500
10/10          0s 13ms/step -
loss: 0.1033 - mean_absolute_error: 0.2422 - val_loss: 0.1005 -
val_mean_absolute_error: 0.2392
Epoch 78/500
10/10          0s 11ms/step -
loss: 0.1027 - mean_absolute_error: 0.2414 - val_loss: 0.1000 -
val_mean_absolute_error: 0.2383
Epoch 79/500
10/10          0s 5ms/step - loss:
0.1021 - mean_absolute_error: 0.2405 - val_loss: 0.0994 -
```

val_mean_absolute_error: 0.2374
Epoch 80/500
10/10   0s 7ms/step - loss:
0.1015 - mean_absolute_error: 0.2397 - val_loss: 0.0989 -
val_mean_absolute_error: 0.2366
Epoch 81/500
10/10   0s 6ms/step - loss:
0.1010 - mean_absolute_error: 0.2388 - val_loss: 0.0984 -
val_mean_absolute_error: 0.2357
Epoch 82/500
10/10   0s 5ms/step - loss:
0.1004 - mean_absolute_error: 0.2379 - val_loss: 0.0978 -
val_mean_absolute_error: 0.2348
Epoch 83/500
10/10   0s 6ms/step - loss:
0.0998 - mean_absolute_error: 0.2371 - val_loss: 0.0973 -
val_mean_absolute_error: 0.2339
Epoch 84/500
10/10   0s 7ms/step - loss:
0.0992 - mean_absolute_error: 0.2362 - val_loss: 0.0968 -
val_mean_absolute_error: 0.2331
Epoch 85/500
10/10   0s 8ms/step - loss:
0.0987 - mean_absolute_error: 0.2354 - val_loss: 0.0963 -
val_mean_absolute_error: 0.2323
Epoch 86/500
10/10   0s 6ms/step - loss:
0.0981 - mean_absolute_error: 0.2345 - val_loss: 0.0957 -
val_mean_absolute_error: 0.2315
Epoch 87/500
10/10   0s 7ms/step - loss:
0.0975 - mean_absolute_error: 0.2337 - val_loss: 0.0952 -
val_mean_absolute_error: 0.2307
Epoch 88/500
10/10   0s 5ms/step - loss:
0.0970 - mean_absolute_error: 0.2328 - val_loss: 0.0947 -
val_mean_absolute_error: 0.2299
Epoch 89/500
10/10   0s 6ms/step - loss:
0.0964 - mean_absolute_error: 0.2320 - val_loss: 0.0942 -
val_mean_absolute_error: 0.2292
Epoch 90/500
10/10   0s 5ms/step - loss:
0.0958 - mean_absolute_error: 0.2312 - val_loss: 0.0937 -
val_mean_absolute_error: 0.2284
Epoch 91/500
10/10   0s 6ms/step - loss:
0.0953 - mean_absolute_error: 0.2304 - val_loss: 0.0931 -

val_mean_absolute_error: 0.2276
Epoch 92/500
10/10   0s 5ms/step - loss:
0.0947 - mean_absolute_error: 0.2295 - val_loss: 0.0926 -
val_mean_absolute_error: 0.2267
Epoch 93/500
10/10   0s 6ms/step - loss:
0.0941 - mean_absolute_error: 0.2287 - val_loss: 0.0921 -
val_mean_absolute_error: 0.2260
Epoch 94/500
10/10   0s 7ms/step - loss:
0.0936 - mean_absolute_error: 0.2279 - val_loss: 0.0916 -
val_mean_absolute_error: 0.2251
Epoch 95/500
10/10   0s 7ms/step - loss:
0.0930 - mean_absolute_error: 0.2270 - val_loss: 0.0911 -
val_mean_absolute_error: 0.2243
Epoch 96/500
10/10   0s 6ms/step - loss:
0.0924 - mean_absolute_error: 0.2262 - val_loss: 0.0906 -
val_mean_absolute_error: 0.2235
Epoch 97/500
10/10   0s 5ms/step - loss:
0.0919 - mean_absolute_error: 0.2253 - val_loss: 0.0901 -
val_mean_absolute_error: 0.2228
Epoch 98/500
10/10   0s 6ms/step - loss:
0.0913 - mean_absolute_error: 0.2246 - val_loss: 0.0896 -
val_mean_absolute_error: 0.2220
Epoch 99/500
10/10   0s 6ms/step - loss:
0.0908 - mean_absolute_error: 0.2237 - val_loss: 0.0891 -
val_mean_absolute_error: 0.2212
Epoch 100/500
10/10   0s 5ms/step - loss:
0.0902 - mean_absolute_error: 0.2230 - val_loss: 0.0886 -
val_mean_absolute_error: 0.2204
Epoch 101/500
10/10   0s 5ms/step - loss:
0.0897 - mean_absolute_error: 0.2221 - val_loss: 0.0881 -
val_mean_absolute_error: 0.2196
Epoch 102/500
10/10   0s 5ms/step - loss:
0.0891 - mean_absolute_error: 0.2213 - val_loss: 0.0876 -
val_mean_absolute_error: 0.2189
Epoch 103/500
10/10   0s 5ms/step - loss:
0.0886 - mean_absolute_error: 0.2205 - val_loss: 0.0871 -

val_mean_absolute_error: 0.2181
Epoch 104/500
10/10   0s 7ms/step - loss:
0.0881 - mean_absolute_error: 0.2197 - val_loss: 0.0866 -
val_mean_absolute_error: 0.2174
Epoch 105/500
10/10   0s 5ms/step - loss:
0.0875 - mean_absolute_error: 0.2189 - val_loss: 0.0861 -
val_mean_absolute_error: 0.2166
Epoch 106/500
10/10   0s 7ms/step - loss:
0.0870 - mean_absolute_error: 0.2180 - val_loss: 0.0856 -
val_mean_absolute_error: 0.2159
Epoch 107/500
10/10   0s 5ms/step - loss:
0.0864 - mean_absolute_error: 0.2172 - val_loss: 0.0851 -
val_mean_absolute_error: 0.2151
Epoch 108/500
10/10   0s 7ms/step - loss:
0.0859 - mean_absolute_error: 0.2164 - val_loss: 0.0847 -
val_mean_absolute_error: 0.2144
Epoch 109/500
10/10   0s 5ms/step - loss:
0.0853 - mean_absolute_error: 0.2156 - val_loss: 0.0842 -
val_mean_absolute_error: 0.2137
Epoch 110/500
10/10   0s 5ms/step - loss:
0.0848 - mean_absolute_error: 0.2148 - val_loss: 0.0837 -
val_mean_absolute_error: 0.2130
Epoch 111/500
10/10   0s 8ms/step - loss:
0.0843 - mean_absolute_error: 0.2140 - val_loss: 0.0832 -
val_mean_absolute_error: 0.2123
Epoch 112/500
10/10   0s 6ms/step - loss:
0.0837 - mean_absolute_error: 0.2132 - val_loss: 0.0827 -
val_mean_absolute_error: 0.2115
Epoch 113/500
10/10   0s 6ms/step - loss:
0.0832 - mean_absolute_error: 0.2125 - val_loss: 0.0823 -
val_mean_absolute_error: 0.2108
Epoch 114/500
10/10   0s 7ms/step - loss:
0.0827 - mean_absolute_error: 0.2117 - val_loss: 0.0818 -
val_mean_absolute_error: 0.2101
Epoch 115/500
10/10   0s 5ms/step - loss:
0.0822 - mean_absolute_error: 0.2109 - val_loss: 0.0813 -

val_mean_absolute_error: 0.2094
Epoch 116/500
10/10   0s 7ms/step - loss:
0.0817 - mean_absolute_error: 0.2102 - val_loss: 0.0809 -
val_mean_absolute_error: 0.2087
Epoch 117/500
10/10   0s 7ms/step - loss:
0.0812 - mean_absolute_error: 0.2094 - val_loss: 0.0804 -
val_mean_absolute_error: 0.2080
Epoch 118/500
10/10   0s 7ms/step - loss:
0.0807 - mean_absolute_error: 0.2087 - val_loss: 0.0799 -
val_mean_absolute_error: 0.2073
Epoch 119/500
10/10   0s 5ms/step - loss:
0.0802 - mean_absolute_error: 0.2079 - val_loss: 0.0795 -
val_mean_absolute_error: 0.2067
Epoch 120/500
10/10   0s 8ms/step - loss:
0.0797 - mean_absolute_error: 0.2072 - val_loss: 0.0790 -
val_mean_absolute_error: 0.2060
Epoch 121/500
10/10   0s 7ms/step - loss:
0.0792 - mean_absolute_error: 0.2064 - val_loss: 0.0786 -
val_mean_absolute_error: 0.2053
Epoch 122/500
10/10   0s 6ms/step - loss:
0.0787 - mean_absolute_error: 0.2057 - val_loss: 0.0781 -
val_mean_absolute_error: 0.2047
Epoch 123/500
10/10   0s 5ms/step - loss:
0.0782 - mean_absolute_error: 0.2049 - val_loss: 0.0777 -
val_mean_absolute_error: 0.2040
Epoch 124/500
10/10   0s 5ms/step - loss:
0.0777 - mean_absolute_error: 0.2042 - val_loss: 0.0773 -
val_mean_absolute_error: 0.2034
Epoch 125/500
10/10   0s 5ms/step - loss:
0.0772 - mean_absolute_error: 0.2036 - val_loss: 0.0768 -
val_mean_absolute_error: 0.2027
Epoch 126/500
10/10   0s 5ms/step - loss:
0.0767 - mean_absolute_error: 0.2028 - val_loss: 0.0764 -
val_mean_absolute_error: 0.2021
Epoch 127/500
10/10   0s 7ms/step - loss:
0.0762 - mean_absolute_error: 0.2022 - val_loss: 0.0759 -

val_mean_absolute_error: 0.2015
Epoch 128/500
10/10   0s 6ms/step - loss:
0.0758 - mean_absolute_error: 0.2015 - val_loss: 0.0755 -
val_mean_absolute_error: 0.2008
Epoch 129/500
10/10   0s 5ms/step - loss:
0.0753 - mean_absolute_error: 0.2008 - val_loss: 0.0751 -
val_mean_absolute_error: 0.2002
Epoch 130/500
10/10   0s 5ms/step - loss:
0.0748 - mean_absolute_error: 0.2001 - val_loss: 0.0746 -
val_mean_absolute_error: 0.1996
Epoch 131/500
10/10   0s 5ms/step - loss:
0.0744 - mean_absolute_error: 0.1994 - val_loss: 0.0742 -
val_mean_absolute_error: 0.1990
Epoch 132/500
10/10   0s 7ms/step - loss:
0.0739 - mean_absolute_error: 0.1987 - val_loss: 0.0738 -
val_mean_absolute_error: 0.1984
Epoch 133/500
10/10   0s 5ms/step - loss:
0.0734 - mean_absolute_error: 0.1980 - val_loss: 0.0734 -
val_mean_absolute_error: 0.1978
Epoch 134/500
10/10   0s 7ms/step - loss:
0.0730 - mean_absolute_error: 0.1973 - val_loss: 0.0730 -
val_mean_absolute_error: 0.1972
Epoch 135/500
10/10   0s 5ms/step - loss:
0.0725 - mean_absolute_error: 0.1966 - val_loss: 0.0725 -
val_mean_absolute_error: 0.1966
Epoch 136/500
10/10   0s 7ms/step - loss:
0.0721 - mean_absolute_error: 0.1959 - val_loss: 0.0721 -
val_mean_absolute_error: 0.1961
Epoch 137/500
10/10   0s 8ms/step - loss:
0.0716 - mean_absolute_error: 0.1952 - val_loss: 0.0717 -
val_mean_absolute_error: 0.1955
Epoch 138/500
10/10   0s 7ms/step - loss:
0.0712 - mean_absolute_error: 0.1945 - val_loss: 0.0713 -
val_mean_absolute_error: 0.1950
Epoch 139/500
10/10   0s 5ms/step - loss:
0.0708 - mean_absolute_error: 0.1939 - val_loss: 0.0709 -

val_mean_absolute_error: 0.1944
Epoch 140/500
10/10   0s 5ms/step - loss:
0.0703 - mean_absolute_error: 0.1932 - val_loss: 0.0705 -
val_mean_absolute_error: 0.1938
Epoch 141/500
10/10   0s 5ms/step - loss:
0.0699 - mean_absolute_error: 0.1926 - val_loss: 0.0701 -
val_mean_absolute_error: 0.1933
Epoch 142/500
10/10   0s 7ms/step - loss:
0.0695 - mean_absolute_error: 0.1919 - val_loss: 0.0697 -
val_mean_absolute_error: 0.1928
Epoch 143/500
10/10   0s 7ms/step - loss:
0.0691 - mean_absolute_error: 0.1912 - val_loss: 0.0693 -
val_mean_absolute_error: 0.1923
Epoch 144/500
10/10   0s 9ms/step - loss:
0.0686 - mean_absolute_error: 0.1906 - val_loss: 0.0689 -
val_mean_absolute_error: 0.1917
Epoch 145/500
10/10   0s 8ms/step - loss:
0.0682 - mean_absolute_error: 0.1899 - val_loss: 0.0685 -
val_mean_absolute_error: 0.1912
Epoch 146/500
10/10   0s 5ms/step - loss:
0.0678 - mean_absolute_error: 0.1893 - val_loss: 0.0681 -
val_mean_absolute_error: 0.1906
Epoch 147/500
10/10   0s 5ms/step - loss:
0.0674 - mean_absolute_error: 0.1886 - val_loss: 0.0677 -
val_mean_absolute_error: 0.1901
Epoch 148/500
10/10   0s 5ms/step - loss:
0.0670 - mean_absolute_error: 0.1880 - val_loss: 0.0673 -
val_mean_absolute_error: 0.1896
Epoch 149/500
10/10   0s 5ms/step - loss:
0.0666 - mean_absolute_error: 0.1874 - val_loss: 0.0670 -
val_mean_absolute_error: 0.1891
Epoch 150/500
10/10   0s 7ms/step - loss:
0.0662 - mean_absolute_error: 0.1868 - val_loss: 0.0666 -
val_mean_absolute_error: 0.1885
Epoch 151/500
10/10   0s 7ms/step - loss:
0.0658 - mean_absolute_error: 0.1861 - val_loss: 0.0662 -

val_mean_absolute_error: 0.1880
Epoch 152/500
10/10   0s 5ms/step - loss:
0.0654 - mean_absolute_error: 0.1855 - val_loss: 0.0658 -
val_mean_absolute_error: 0.1875
Epoch 153/500
10/10   0s 6ms/step - loss:
0.0650 - mean_absolute_error: 0.1849 - val_loss: 0.0655 -
val_mean_absolute_error: 0.1870
Epoch 154/500
10/10   0s 5ms/step - loss:
0.0646 - mean_absolute_error: 0.1843 - val_loss: 0.0651 -
val_mean_absolute_error: 0.1864
Epoch 155/500
10/10   0s 6ms/step - loss:
0.0642 - mean_absolute_error: 0.1836 - val_loss: 0.0647 -
val_mean_absolute_error: 0.1859
Epoch 156/500
10/10   0s 5ms/step - loss:
0.0638 - mean_absolute_error: 0.1830 - val_loss: 0.0644 -
val_mean_absolute_error: 0.1854
Epoch 157/500
10/10   0s 5ms/step - loss:
0.0634 - mean_absolute_error: 0.1824 - val_loss: 0.0640 -
val_mean_absolute_error: 0.1848
Epoch 158/500
10/10   0s 5ms/step - loss:
0.0630 - mean_absolute_error: 0.1817 - val_loss: 0.0636 -
val_mean_absolute_error: 0.1842
Epoch 159/500
10/10   0s 5ms/step - loss:
0.0626 - mean_absolute_error: 0.1810 - val_loss: 0.0632 -
val_mean_absolute_error: 0.1837
Epoch 160/500
10/10   0s 6ms/step - loss:
0.0622 - mean_absolute_error: 0.1804 - val_loss: 0.0629 -
val_mean_absolute_error: 0.1831
Epoch 161/500
10/10   0s 6ms/step - loss:
0.0618 - mean_absolute_error: 0.1797 - val_loss: 0.0625 -
val_mean_absolute_error: 0.1826
Epoch 162/500
10/10   0s 10ms/step -
loss: 0.0614 - mean_absolute_error: 0.1791 - val_loss: 0.0621 -
val_mean_absolute_error: 0.1820
Epoch 163/500
10/10   0s 8ms/step - loss:
0.0610 - mean_absolute_error: 0.1785 - val_loss: 0.0618 -

val_mean_absolute_error: 0.1815
Epoch 164/500
10/10   0s 9ms/step - loss:
0.0607 - mean_absolute_error: 0.1778 - val_loss: 0.0614 -
val_mean_absolute_error: 0.1809
Epoch 165/500
10/10   0s 8ms/step - loss:
0.0603 - mean_absolute_error: 0.1772 - val_loss: 0.0610 -
val_mean_absolute_error: 0.1804
Epoch 166/500
10/10   0s 7ms/step - loss:
0.0599 - mean_absolute_error: 0.1766 - val_loss: 0.0607 -
val_mean_absolute_error: 0.1799
Epoch 167/500
10/10   0s 8ms/step - loss:
0.0595 - mean_absolute_error: 0.1760 - val_loss: 0.0603 -
val_mean_absolute_error: 0.1793
Epoch 168/500
10/10   0s 8ms/step - loss:
0.0592 - mean_absolute_error: 0.1754 - val_loss: 0.0600 -
val_mean_absolute_error: 0.1788
Epoch 169/500
10/10   0s 9ms/step - loss:
0.0588 - mean_absolute_error: 0.1748 - val_loss: 0.0596 -
val_mean_absolute_error: 0.1782
Epoch 170/500
10/10   0s 8ms/step - loss:
0.0584 - mean_absolute_error: 0.1742 - val_loss: 0.0593 -
val_mean_absolute_error: 0.1777
Epoch 171/500
10/10   0s 8ms/step - loss:
0.0581 - mean_absolute_error: 0.1736 - val_loss: 0.0589 -
val_mean_absolute_error: 0.1771
Epoch 172/500
10/10   0s 7ms/step - loss:
0.0577 - mean_absolute_error: 0.1730 - val_loss: 0.0586 -
val_mean_absolute_error: 0.1767
Epoch 173/500
10/10   0s 9ms/step - loss:
0.0574 - mean_absolute_error: 0.1725 - val_loss: 0.0582 -
val_mean_absolute_error: 0.1761
Epoch 174/500
10/10   0s 8ms/step - loss:
0.0570 - mean_absolute_error: 0.1719 - val_loss: 0.0579 -
val_mean_absolute_error: 0.1756
Epoch 175/500
10/10   0s 10ms/step -
loss: 0.0567 - mean_absolute_error: 0.1714 - val_loss: 0.0575 -

val_mean_absolute_error: 0.1751
Epoch 176/500
10/10   0s 13ms/step -
loss: 0.0563 - mean_absolute_error: 0.1708 - val_loss: 0.0572 -
val_mean_absolute_error: 0.1745
Epoch 177/500
10/10   0s 9ms/step - loss:
0.0560 - mean_absolute_error: 0.1702 - val_loss: 0.0569 -
val_mean_absolute_error: 0.1740
Epoch 178/500
10/10   0s 9ms/step - loss:
0.0556 - mean_absolute_error: 0.1696 - val_loss: 0.0565 -
val_mean_absolute_error: 0.1735
Epoch 179/500
10/10   0s 9ms/step - loss:
0.0553 - mean_absolute_error: 0.1691 - val_loss: 0.0562 -
val_mean_absolute_error: 0.1729
Epoch 180/500
10/10   0s 6ms/step - loss:
0.0549 - mean_absolute_error: 0.1685 - val_loss: 0.0559 -
val_mean_absolute_error: 0.1725
Epoch 181/500
10/10   0s 6ms/step - loss:
0.0546 - mean_absolute_error: 0.1679 - val_loss: 0.0556 -
val_mean_absolute_error: 0.1719
Epoch 182/500
10/10   0s 5ms/step - loss:
0.0542 - mean_absolute_error: 0.1674 - val_loss: 0.0552 -
val_mean_absolute_error: 0.1714
Epoch 183/500
10/10   0s 5ms/step - loss:
0.0539 - mean_absolute_error: 0.1668 - val_loss: 0.0549 -
val_mean_absolute_error: 0.1708
Epoch 184/500
10/10   0s 5ms/step - loss:
0.0536 - mean_absolute_error: 0.1663 - val_loss: 0.0546 -
val_mean_absolute_error: 0.1703
Epoch 185/500
10/10   0s 5ms/step - loss:
0.0532 - mean_absolute_error: 0.1657 - val_loss: 0.0543 -
val_mean_absolute_error: 0.1698
Epoch 186/500
10/10   0s 5ms/step - loss:
0.0529 - mean_absolute_error: 0.1652 - val_loss: 0.0539 -
val_mean_absolute_error: 0.1693
Epoch 187/500
10/10   0s 5ms/step - loss:
0.0526 - mean_absolute_error: 0.1647 - val_loss: 0.0536 -

val_mean_absolute_error: 0.1687
Epoch 188/500
10/10   0s 5ms/step - loss:
0.0522 - mean_absolute_error: 0.1641 - val_loss: 0.0533 -
val_mean_absolute_error: 0.1683
Epoch 189/500
10/10   0s 5ms/step - loss:
0.0519 - mean_absolute_error: 0.1636 - val_loss: 0.0530 -
val_mean_absolute_error: 0.1676
Epoch 190/500
10/10   0s 7ms/step - loss:
0.0516 - mean_absolute_error: 0.1631 - val_loss: 0.0527 -
val_mean_absolute_error: 0.1672
Epoch 191/500
10/10   0s 6ms/step - loss:
0.0513 - mean_absolute_error: 0.1626 - val_loss: 0.0524 -
val_mean_absolute_error: 0.1666
Epoch 192/500
10/10   0s 7ms/step - loss:
0.0510 - mean_absolute_error: 0.1622 - val_loss: 0.0521 -
val_mean_absolute_error: 0.1660
Epoch 193/500
10/10   0s 7ms/step - loss:
0.0506 - mean_absolute_error: 0.1616 - val_loss: 0.0518 -
val_mean_absolute_error: 0.1655
Epoch 194/500
10/10   0s 7ms/step - loss:
0.0503 - mean_absolute_error: 0.1612 - val_loss: 0.0514 -
val_mean_absolute_error: 0.1650
Epoch 195/500
10/10   0s 5ms/step - loss:
0.0500 - mean_absolute_error: 0.1607 - val_loss: 0.0512 -
val_mean_absolute_error: 0.1646
Epoch 196/500
10/10   0s 7ms/step - loss:
0.0497 - mean_absolute_error: 0.1602 - val_loss: 0.0509 -
val_mean_absolute_error: 0.1641
Epoch 197/500
10/10   0s 5ms/step - loss:
0.0494 - mean_absolute_error: 0.1597 - val_loss: 0.0506 -
val_mean_absolute_error: 0.1635
Epoch 198/500
10/10   0s 8ms/step - loss:
0.0491 - mean_absolute_error: 0.1592 - val_loss: 0.0503 -
val_mean_absolute_error: 0.1630
Epoch 199/500
10/10   0s 8ms/step - loss:
0.0488 - mean_absolute_error: 0.1588 - val_loss: 0.0499 -

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val_mean_absolute_error: 0.1624
Epoch 200/500
10/10          0s 5ms/step - loss:
0.0485 - mean_absolute_error: 0.1583 - val_loss: 0.0497 -
val_mean_absolute_error: 0.1623
Epoch 201/500
10/10          0s 7ms/step - loss:
0.0482 - mean_absolute_error: 0.1579 - val_loss: 0.0494 -
val_mean_absolute_error: 0.1617
Epoch 202/500
10/10          0s 5ms/step - loss:
0.0479 - mean_absolute_error: 0.1574 - val_loss: 0.0490 -
val_mean_absolute_error: 0.1610
Epoch 203/500
10/10          0s 5ms/step - loss:
0.0475 - mean_absolute_error: 0.1568 - val_loss: 0.0488 -
val_mean_absolute_error: 0.1607
Epoch 204/500
10/10          0s 5ms/step - loss:
0.0473 - mean_absolute_error: 0.1564 - val_loss: 0.0485 -
val_mean_absolute_error: 0.1602
Epoch 205/500
10/10          0s 7ms/step - loss:
0.0470 - mean_absolute_error: 0.1559 - val_loss: 0.0482 -
val_mean_absolute_error: 0.1598
Epoch 206/500
10/10          0s 6ms/step - loss:
0.0467 - mean_absolute_error: 0.1555 - val_loss: 0.0479 -
val_mean_absolute_error: 0.1594
Epoch 207/500
10/10          0s 5ms/step - loss:
0.0464 - mean_absolute_error: 0.1551 - val_loss: 0.0476 -
val_mean_absolute_error: 0.1589
Epoch 208/500
10/10          0s 6ms/step - loss:
0.0461 - mean_absolute_error: 0.1546 - val_loss: 0.0473 -
val_mean_absolute_error: 0.1585
Epoch 209/500
10/10          0s 8ms/step - loss:
0.0458 - mean_absolute_error: 0.1542 - val_loss: 0.0470 -
val_mean_absolute_error: 0.1582
Epoch 210/500
10/10          0s 5ms/step - loss:
0.0455 - mean_absolute_error: 0.1537 - val_loss: 0.0467 -
val_mean_absolute_error: 0.1575
Epoch 211/500
10/10          0s 5ms/step - loss:
0.0452 - mean_absolute_error: 0.1533 - val_loss: 0.0464 -
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val_mean_absolute_error: 0.1572
Epoch 212/500
10/10   0s 7ms/step - loss:
0.0449 - mean_absolute_error: 0.1528 - val_loss: 0.0461 -
val_mean_absolute_error: 0.1567
Epoch 213/500
10/10   0s 7ms/step - loss:
0.0446 - mean_absolute_error: 0.1523 - val_loss: 0.0459 -
val_mean_absolute_error: 0.1562
Epoch 214/500
10/10   0s 7ms/step - loss:
0.0443 - mean_absolute_error: 0.1518 - val_loss: 0.0456 -
val_mean_absolute_error: 0.1560
Epoch 215/500
10/10   0s 7ms/step - loss:
0.0441 - mean_absolute_error: 0.1515 - val_loss: 0.0454 -
val_mean_absolute_error: 0.1556
Epoch 216/500
10/10   0s 6ms/step - loss:
0.0438 - mean_absolute_error: 0.1510 - val_loss: 0.0451 -
val_mean_absolute_error: 0.1552
Epoch 217/500
10/10   0s 7ms/step - loss:
0.0435 - mean_absolute_error: 0.1505 - val_loss: 0.0448 -
val_mean_absolute_error: 0.1546
Epoch 218/500
10/10   0s 5ms/step - loss:
0.0432 - mean_absolute_error: 0.1500 - val_loss: 0.0445 -
val_mean_absolute_error: 0.1542
Epoch 219/500
10/10   0s 6ms/step - loss:
0.0429 - mean_absolute_error: 0.1495 - val_loss: 0.0442 -
val_mean_absolute_error: 0.1538
Epoch 220/500
10/10   0s 7ms/step - loss:
0.0426 - mean_absolute_error: 0.1491 - val_loss: 0.0439 -
val_mean_absolute_error: 0.1533
Epoch 221/500
10/10   0s 5ms/step - loss:
0.0424 - mean_absolute_error: 0.1486 - val_loss: 0.0436 -
val_mean_absolute_error: 0.1527
Epoch 222/500
10/10   0s 5ms/step - loss:
0.0421 - mean_absolute_error: 0.1481 - val_loss: 0.0434 -
val_mean_absolute_error: 0.1523
Epoch 223/500
10/10   0s 6ms/step - loss:
0.0418 - mean_absolute_error: 0.1476 - val_loss: 0.0430 -

val_mean_absolute_error: 0.1516
Epoch 224/500
10/10   0s 5ms/step - loss:
0.0415 - mean_absolute_error: 0.1471 - val_loss: 0.0428 -
val_mean_absolute_error: 0.1513
Epoch 225/500
10/10   0s 6ms/step - loss:
0.0412 - mean_absolute_error: 0.1466 - val_loss: 0.0425 -
val_mean_absolute_error: 0.1509
Epoch 226/500
10/10   0s 7ms/step - loss:
0.0410 - mean_absolute_error: 0.1462 - val_loss: 0.0422 -
val_mean_absolute_error: 0.1503
Epoch 227/500
10/10   0s 7ms/step - loss:
0.0407 - mean_absolute_error: 0.1457 - val_loss: 0.0419 -
val_mean_absolute_error: 0.1499
Epoch 228/500
10/10   0s 5ms/step - loss:
0.0404 - mean_absolute_error: 0.1452 - val_loss: 0.0417 -
val_mean_absolute_error: 0.1496
Epoch 229/500
10/10   0s 5ms/step - loss:
0.0402 - mean_absolute_error: 0.1447 - val_loss: 0.0414 -
val_mean_absolute_error: 0.1491
Epoch 230/500
10/10   0s 7ms/step - loss:
0.0399 - mean_absolute_error: 0.1443 - val_loss: 0.0411 -
val_mean_absolute_error: 0.1485
Epoch 231/500
10/10   0s 7ms/step - loss:
0.0396 - mean_absolute_error: 0.1438 - val_loss: 0.0409 -
val_mean_absolute_error: 0.1483
Epoch 232/500
10/10   0s 7ms/step - loss:
0.0394 - mean_absolute_error: 0.1434 - val_loss: 0.0406 -
val_mean_absolute_error: 0.1478
Epoch 233/500
10/10   0s 5ms/step - loss:
0.0391 - mean_absolute_error: 0.1429 - val_loss: 0.0403 -
val_mean_absolute_error: 0.1474
Epoch 234/500
10/10   0s 7ms/step - loss:
0.0388 - mean_absolute_error: 0.1425 - val_loss: 0.0401 -
val_mean_absolute_error: 0.1470
Epoch 235/500
10/10   0s 5ms/step - loss:
0.0386 - mean_absolute_error: 0.1420 - val_loss: 0.0398 -

val_mean_absolute_error: 0.1465
Epoch 236/500
10/10   0s 6ms/step - loss:
0.0383 - mean_absolute_error: 0.1415 - val_loss: 0.0396 -
val_mean_absolute_error: 0.1463
Epoch 237/500
10/10   0s 5ms/step - loss:
0.0381 - mean_absolute_error: 0.1412 - val_loss: 0.0393 -
val_mean_absolute_error: 0.1458
Epoch 238/500
10/10   0s 5ms/step - loss:
0.0378 - mean_absolute_error: 0.1406 - val_loss: 0.0391 -
val_mean_absolute_error: 0.1455
Epoch 239/500
10/10   0s 5ms/step - loss:
0.0375 - mean_absolute_error: 0.1401 - val_loss: 0.0388 -
val_mean_absolute_error: 0.1451
Epoch 240/500
10/10   0s 8ms/step - loss:
0.0373 - mean_absolute_error: 0.1397 - val_loss: 0.0385 -
val_mean_absolute_error: 0.1447
Epoch 241/500
10/10   0s 6ms/step - loss:
0.0370 - mean_absolute_error: 0.1392 - val_loss: 0.0383 -
val_mean_absolute_error: 0.1443
Epoch 242/500
10/10   0s 7ms/step - loss:
0.0368 - mean_absolute_error: 0.1387 - val_loss: 0.0380 -
val_mean_absolute_error: 0.1439
Epoch 243/500
10/10   0s 6ms/step - loss:
0.0365 - mean_absolute_error: 0.1382 - val_loss: 0.0377 -
val_mean_absolute_error: 0.1435
Epoch 244/500
10/10   0s 5ms/step - loss:
0.0362 - mean_absolute_error: 0.1377 - val_loss: 0.0374 -
val_mean_absolute_error: 0.1429
Epoch 245/500
10/10   0s 5ms/step - loss:
0.0360 - mean_absolute_error: 0.1371 - val_loss: 0.0372 -
val_mean_absolute_error: 0.1426
Epoch 246/500
10/10   0s 7ms/step - loss:
0.0357 - mean_absolute_error: 0.1367 - val_loss: 0.0369 -
val_mean_absolute_error: 0.1421
Epoch 247/500
10/10   0s 5ms/step - loss:
0.0354 - mean_absolute_error: 0.1362 - val_loss: 0.0367 -

```
val_mean_absolute_error: 0.1416
Epoch 248/500
10/10            0s 9ms/step - loss:
0.0352 - mean_absolute_error: 0.1357 - val_loss: 0.0364 -
val_mean_absolute_error: 0.1413
Epoch 249/500
10/10            0s 10ms/step -
loss: 0.0349 - mean_absolute_error: 0.1352 - val_loss: 0.0362 -
val_mean_absolute_error: 0.1408
Epoch 250/500
10/10            0s 10ms/step -
loss: 0.0347 - mean_absolute_error: 0.1349 - val_loss: 0.0360 -
val_mean_absolute_error: 0.1404
Epoch 251/500
10/10            0s 10ms/step -
loss: 0.0344 - mean_absolute_error: 0.1344 - val_loss: 0.0357 -
val_mean_absolute_error: 0.1398
Epoch 252/500
10/10            0s 9ms/step - loss:
0.0342 - mean_absolute_error: 0.1339 - val_loss: 0.0354 -
val_mean_absolute_error: 0.1393
Epoch 253/500
10/10            0s 7ms/step - loss:
0.0339 - mean_absolute_error: 0.1334 - val_loss: 0.0352 -
val_mean_absolute_error: 0.1388
Epoch 254/500
10/10            0s 8ms/step - loss:
0.0337 - mean_absolute_error: 0.1329 - val_loss: 0.0350 -
val_mean_absolute_error: 0.1383
Epoch 255/500
10/10            0s 8ms/step - loss:
0.0334 - mean_absolute_error: 0.1324 - val_loss: 0.0347 -
val_mean_absolute_error: 0.1379
Epoch 256/500
10/10            0s 12ms/step -
loss: 0.0331 - mean_absolute_error: 0.1320 - val_loss: 0.0344 -
val_mean_absolute_error: 0.1372
Epoch 257/500
10/10            0s 9ms/step - loss:
0.0329 - mean_absolute_error: 0.1314 - val_loss: 0.0342 -
val_mean_absolute_error: 0.1368
Epoch 258/500
10/10            0s 10ms/step -
loss: 0.0326 - mean_absolute_error: 0.1310 - val_loss: 0.0340 -
val_mean_absolute_error: 0.1364
Epoch 259/500
10/10            0s 8ms/step - loss:
0.0324 - mean_absolute_error: 0.1306 - val_loss: 0.0337 -
```

val_mean_absolute_error: 0.1359
Epoch 260/500
10/10   0s 8ms/step - loss:
0.0322 - mean_absolute_error: 0.1302 - val_loss: 0.0335 -
val_mean_absolute_error: 0.1355
Epoch 261/500
10/10   0s 9ms/step - loss:
0.0319 - mean_absolute_error: 0.1298 - val_loss: 0.0332 -
val_mean_absolute_error: 0.1351
Epoch 262/500
10/10   0s 9ms/step - loss:
0.0317 - mean_absolute_error: 0.1293 - val_loss: 0.0330 -
val_mean_absolute_error: 0.1347
Epoch 263/500
10/10   0s 13ms/step -
loss: 0.0315 - mean_absolute_error: 0.1290 - val_loss: 0.0328 -
val_mean_absolute_error: 0.1343
Epoch 264/500
10/10   0s 11ms/step -
loss: 0.0313 - mean_absolute_error: 0.1286 - val_loss: 0.0325 -
val_mean_absolute_error: 0.1337
Epoch 265/500
10/10   0s 10ms/step -
loss: 0.0310 - mean_absolute_error: 0.1281 - val_loss: 0.0323 -
val_mean_absolute_error: 0.1334
Epoch 266/500
10/10   0s 14ms/step -
loss: 0.0308 - mean_absolute_error: 0.1279 - val_loss: 0.0321 -
val_mean_absolute_error: 0.1329
Epoch 267/500
10/10   0s 7ms/step - loss:
0.0306 - mean_absolute_error: 0.1275 - val_loss: 0.0318 -
val_mean_absolute_error: 0.1323
Epoch 268/500
10/10   0s 11ms/step -
loss: 0.0304 - mean_absolute_error: 0.1270 - val_loss: 0.0316 -
val_mean_absolute_error: 0.1320
Epoch 269/500
10/10   0s 7ms/step - loss:
0.0302 - mean_absolute_error: 0.1267 - val_loss: 0.0314 -
val_mean_absolute_error: 0.1315
Epoch 270/500
10/10   0s 8ms/step - loss:
0.0300 - mean_absolute_error: 0.1263 - val_loss: 0.0311 -
val_mean_absolute_error: 0.1310
Epoch 271/500
10/10   0s 9ms/step - loss:
0.0298 - mean_absolute_error: 0.1259 - val_loss: 0.0310 -

val_mean_absolute_error: 0.1308
Epoch 272/500
10/10   0s 9ms/step - loss:
0.0296 - mean_absolute_error: 0.1256 - val_loss: 0.0307 -
val_mean_absolute_error: 0.1301
Epoch 273/500
10/10   0s 9ms/step - loss:
0.0294 - mean_absolute_error: 0.1252 - val_loss: 0.0305 -
val_mean_absolute_error: 0.1300
Epoch 274/500
10/10   0s 10ms/step -
loss: 0.0292 - mean_absolute_error: 0.1249 - val_loss: 0.0303 -
val_mean_absolute_error: 0.1295
Epoch 275/500
10/10   0s 11ms/step -
loss: 0.0290 - mean_absolute_error: 0.1245 - val_loss: 0.0301 -
val_mean_absolute_error: 0.1290
Epoch 276/500
10/10   0s 10ms/step -
loss: 0.0288 - mean_absolute_error: 0.1242 - val_loss: 0.0299 -
val_mean_absolute_error: 0.1286
Epoch 277/500
10/10   0s 8ms/step - loss:
0.0286 - mean_absolute_error: 0.1238 - val_loss: 0.0297 -
val_mean_absolute_error: 0.1282
Epoch 278/500
10/10   0s 10ms/step -
loss: 0.0283 - mean_absolute_error: 0.1234 - val_loss: 0.0294 -
val_mean_absolute_error: 0.1276
Epoch 279/500
10/10   0s 10ms/step -
loss: 0.0281 - mean_absolute_error: 0.1229 - val_loss: 0.0292 -
val_mean_absolute_error: 0.1273
Epoch 280/500
10/10   0s 9ms/step - loss:
0.0279 - mean_absolute_error: 0.1226 - val_loss: 0.0290 -
val_mean_absolute_error: 0.1269
Epoch 281/500
10/10   0s 10ms/step -
loss: 0.0277 - mean_absolute_error: 0.1222 - val_loss: 0.0287 -
val_mean_absolute_error: 0.1264
Epoch 282/500
10/10   0s 7ms/step - loss:
0.0275 - mean_absolute_error: 0.1218 - val_loss: 0.0285 -
val_mean_absolute_error: 0.1258
Epoch 283/500
10/10   0s 5ms/step - loss:
0.0273 - mean_absolute_error: 0.1215 - val_loss: 0.0283 -

val_mean_absolute_error: 0.1257
Epoch 284/500
10/10   0s 5ms/step - loss:
0.0271 - mean_absolute_error: 0.1211 - val_loss: 0.0281 -
val_mean_absolute_error: 0.1251
Epoch 285/500
10/10   0s 7ms/step - loss:
0.0269 - mean_absolute_error: 0.1207 - val_loss: 0.0279 -
val_mean_absolute_error: 0.1249
Epoch 286/500
10/10   0s 7ms/step - loss:
0.0268 - mean_absolute_error: 0.1204 - val_loss: 0.0277 -
val_mean_absolute_error: 0.1246
Epoch 287/500
10/10   0s 5ms/step - loss:
0.0266 - mean_absolute_error: 0.1200 - val_loss: 0.0275 -
val_mean_absolute_error: 0.1240
Epoch 288/500
10/10   0s 6ms/step - loss:
0.0264 - mean_absolute_error: 0.1196 - val_loss: 0.0273 -
val_mean_absolute_error: 0.1239
Epoch 289/500
10/10   0s 5ms/step - loss:
0.0262 - mean_absolute_error: 0.1193 - val_loss: 0.0271 -
val_mean_absolute_error: 0.1235
Epoch 290/500
10/10   0s 7ms/step - loss:
0.0260 - mean_absolute_error: 0.1190 - val_loss: 0.0269 -
val_mean_absolute_error: 0.1229
Epoch 291/500
10/10   0s 7ms/step - loss:
0.0258 - mean_absolute_error: 0.1186 - val_loss: 0.0268 -
val_mean_absolute_error: 0.1228
Epoch 292/500
10/10   0s 5ms/step - loss:
0.0257 - mean_absolute_error: 0.1183 - val_loss: 0.0266 -
val_mean_absolute_error: 0.1223
Epoch 293/500
10/10   0s 7ms/step - loss:
0.0255 - mean_absolute_error: 0.1180 - val_loss: 0.0263 -
val_mean_absolute_error: 0.1218
Epoch 294/500
10/10   0s 7ms/step - loss:
0.0253 - mean_absolute_error: 0.1177 - val_loss: 0.0262 -
val_mean_absolute_error: 0.1217
Epoch 295/500
10/10   0s 7ms/step - loss:
0.0252 - mean_absolute_error: 0.1173 - val_loss: 0.0260 -

val_mean_absolute_error: 0.1212
Epoch 296/500
10/10   0s 7ms/step - loss:
0.0250 - mean_absolute_error: 0.1170 - val_loss: 0.0258 -
val_mean_absolute_error: 0.1207
Epoch 297/500
10/10   0s 8ms/step - loss:
0.0248 - mean_absolute_error: 0.1167 - val_loss: 0.0256 -
val_mean_absolute_error: 0.1206
Epoch 298/500
10/10   0s 6ms/step - loss:
0.0247 - mean_absolute_error: 0.1164 - val_loss: 0.0254 -
val_mean_absolute_error: 0.1199
Epoch 299/500
10/10   0s 7ms/step - loss:
0.0245 - mean_absolute_error: 0.1161 - val_loss: 0.0253 -
val_mean_absolute_error: 0.1197
Epoch 300/500
10/10   0s 7ms/step - loss:
0.0244 - mean_absolute_error: 0.1158 - val_loss: 0.0251 -
val_mean_absolute_error: 0.1194
Epoch 301/500
10/10   0s 5ms/step - loss:
0.0242 - mean_absolute_error: 0.1155 - val_loss: 0.0249 -
val_mean_absolute_error: 0.1187
Epoch 302/500
10/10   0s 6ms/step - loss:
0.0241 - mean_absolute_error: 0.1152 - val_loss: 0.0247 -
val_mean_absolute_error: 0.1187
Epoch 303/500
10/10   0s 7ms/step - loss:
0.0239 - mean_absolute_error: 0.1149 - val_loss: 0.0245 -
val_mean_absolute_error: 0.1181
Epoch 304/500
10/10   0s 7ms/step - loss:
0.0237 - mean_absolute_error: 0.1146 - val_loss: 0.0244 -
val_mean_absolute_error: 0.1179
Epoch 305/500
10/10   0s 6ms/step - loss:
0.0236 - mean_absolute_error: 0.1143 - val_loss: 0.0241 -
val_mean_absolute_error: 0.1172
Epoch 306/500
10/10   0s 5ms/step - loss:
0.0234 - mean_absolute_error: 0.1138 - val_loss: 0.0239 -
val_mean_absolute_error: 0.1171
Epoch 307/500
10/10   0s 6ms/step - loss:
0.0233 - mean_absolute_error: 0.1137 - val_loss: 0.0237 -

```
val_mean_absolute_error: 0.1167
Epoch 308/500
10/10              0s 7ms/step - loss:
0.0231 - mean_absolute_error: 0.1133 - val_loss: 0.0236 -
val_mean_absolute_error: 0.1163
Epoch 309/500
10/10              0s 5ms/step - loss:
0.0230 - mean_absolute_error: 0.1130 - val_loss: 0.0234 -
val_mean_absolute_error: 0.1161
Epoch 310/500
10/10              0s 7ms/step - loss:
0.0228 - mean_absolute_error: 0.1128 - val_loss: 0.0233 -
val_mean_absolute_error: 0.1158
Epoch 311/500
10/10              0s 5ms/step - loss:
0.0227 - mean_absolute_error: 0.1125 - val_loss: 0.0231 -
val_mean_absolute_error: 0.1155
Epoch 312/500
10/10              0s 5ms/step - loss:
0.0226 - mean_absolute_error: 0.1122 - val_loss: 0.0230 -
val_mean_absolute_error: 0.1154
Epoch 313/500
10/10              0s 5ms/step - loss:
0.0224 - mean_absolute_error: 0.1119 - val_loss: 0.0228 -
val_mean_absolute_error: 0.1149
Epoch 314/500
10/10              0s 6ms/step - loss:
0.0223 - mean_absolute_error: 0.1117 - val_loss: 0.0227 -
val_mean_absolute_error: 0.1148
Epoch 315/500
10/10              0s 5ms/step - loss:
0.0221 - mean_absolute_error: 0.1115 - val_loss: 0.0225 -
val_mean_absolute_error: 0.1144
Epoch 316/500
10/10              0s 5ms/step - loss:
0.0220 - mean_absolute_error: 0.1112 - val_loss: 0.0223 -
val_mean_absolute_error: 0.1142
Epoch 317/500
10/10              0s 7ms/step - loss:
0.0219 - mean_absolute_error: 0.1110 - val_loss: 0.0222 -
val_mean_absolute_error: 0.1138
Epoch 318/500
10/10              0s 7ms/step - loss:
0.0217 - mean_absolute_error: 0.1107 - val_loss: 0.0220 -
val_mean_absolute_error: 0.1136
Epoch 319/500
10/10              0s 6ms/step - loss:
0.0216 - mean_absolute_error: 0.1105 - val_loss: 0.0219 -
```

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val_mean_absolute_error: 0.1134
Epoch 320/500
10/10              0s 6ms/step - loss:
0.0215 - mean_absolute_error: 0.1102 - val_loss: 0.0217 -
val_mean_absolute_error: 0.1130
Epoch 321/500
10/10              0s 7ms/step - loss:
0.0213 - mean_absolute_error: 0.1100 - val_loss: 0.0216 -
val_mean_absolute_error: 0.1129
Epoch 322/500
10/10              0s 7ms/step - loss:
0.0212 - mean_absolute_error: 0.1097 - val_loss: 0.0215 -
val_mean_absolute_error: 0.1126
Epoch 323/500
10/10              0s 7ms/step - loss:
0.0211 - mean_absolute_error: 0.1095 - val_loss: 0.0213 -
val_mean_absolute_error: 0.1122
Epoch 324/500
10/10              0s 5ms/step - loss:
0.0209 - mean_absolute_error: 0.1092 - val_loss: 0.0212 -
val_mean_absolute_error: 0.1121
Epoch 325/500
10/10              0s 7ms/step - loss:
0.0208 - mean_absolute_error: 0.1089 - val_loss: 0.0211 -
val_mean_absolute_error: 0.1118
Epoch 326/500
10/10              0s 7ms/step - loss:
0.0207 - mean_absolute_error: 0.1087 - val_loss: 0.0209 -
val_mean_absolute_error: 0.1113
Epoch 327/500
10/10              0s 7ms/step - loss:
0.0206 - mean_absolute_error: 0.1083 - val_loss: 0.0208 -
val_mean_absolute_error: 0.1112
Epoch 328/500
10/10              0s 5ms/step - loss:
0.0205 - mean_absolute_error: 0.1082 - val_loss: 0.0206 -
val_mean_absolute_error: 0.1109
Epoch 329/500
10/10              0s 7ms/step - loss:
0.0204 - mean_absolute_error: 0.1080 - val_loss: 0.0204 -
val_mean_absolute_error: 0.1104
Epoch 330/500
10/10              0s 6ms/step - loss:
0.0203 - mean_absolute_error: 0.1078 - val_loss: 0.0204 -
val_mean_absolute_error: 0.1105
Epoch 331/500
10/10              0s 7ms/step - loss:
0.0202 - mean_absolute_error: 0.1077 - val_loss: 0.0202 -
```

val_mean_absolute_error: 0.1099
Epoch 332/500
10/10   0s 7ms/step - loss:
0.0200 - mean_absolute_error: 0.1074 - val_loss: 0.0201 -
val_mean_absolute_error: 0.1099
Epoch 333/500
10/10   0s 5ms/step - loss:
0.0199 - mean_absolute_error: 0.1073 - val_loss: 0.0200 -
val_mean_absolute_error: 0.1097
Epoch 334/500
10/10   0s 7ms/step - loss:
0.0199 - mean_absolute_error: 0.1072 - val_loss: 0.0198 -
val_mean_absolute_error: 0.1091
Epoch 335/500
10/10   0s 7ms/step - loss:
0.0197 - mean_absolute_error: 0.1069 - val_loss: 0.0198 -
val_mean_absolute_error: 0.1093
Epoch 336/500
10/10   0s 5ms/step - loss:
0.0197 - mean_absolute_error: 0.1068 - val_loss: 0.0197 -
val_mean_absolute_error: 0.1088
Epoch 337/500
10/10   0s 5ms/step - loss:
0.0195 - mean_absolute_error: 0.1065 - val_loss: 0.0195 -
val_mean_absolute_error: 0.1087
Epoch 338/500
10/10   0s 5ms/step - loss:
0.0195 - mean_absolute_error: 0.1064 - val_loss: 0.0194 -
val_mean_absolute_error: 0.1083
Epoch 339/500
10/10   0s 7ms/step - loss:
0.0194 - mean_absolute_error: 0.1062 - val_loss: 0.0190 -
val_mean_absolute_error: 0.1072
Epoch 340/500
10/10   0s 6ms/step - loss:
0.0192 - mean_absolute_error: 0.1058 - val_loss: 0.0189 -
val_mean_absolute_error: 0.1071
Epoch 341/500
10/10   0s 5ms/step - loss:
0.0192 - mean_absolute_error: 0.1058 - val_loss: 0.0188 -
val_mean_absolute_error: 0.1068
Epoch 342/500
10/10   0s 5ms/step - loss:
0.0191 - mean_absolute_error: 0.1056 - val_loss: 0.0186 -
val_mean_absolute_error: 0.1065
Epoch 343/500
10/10   0s 5ms/step - loss:
0.0190 - mean_absolute_error: 0.1054 - val_loss: 0.0185 -

val_mean_absolute_error: 0.1062
Epoch 344/500
10/10   0s 7ms/step - loss:
0.0189 - mean_absolute_error: 0.1052 - val_loss: 0.0184 -
val_mean_absolute_error: 0.1059
Epoch 345/500
10/10   0s 6ms/step - loss:
0.0188 - mean_absolute_error: 0.1051 - val_loss: 0.0183 -
val_mean_absolute_error: 0.1054
Epoch 346/500
10/10   0s 8ms/step - loss:
0.0187 - mean_absolute_error: 0.1049 - val_loss: 0.0182 -
val_mean_absolute_error: 0.1056
Epoch 347/500
10/10   0s 7ms/step - loss:
0.0186 - mean_absolute_error: 0.1048 - val_loss: 0.0179 -
val_mean_absolute_error: 0.1045
Epoch 348/500
10/10   0s 5ms/step - loss:
0.0185 - mean_absolute_error: 0.1045 - val_loss: 0.0179 -
val_mean_absolute_error: 0.1045
Epoch 349/500
10/10   0s 6ms/step - loss:
0.0184 - mean_absolute_error: 0.1043 - val_loss: 0.0177 -
val_mean_absolute_error: 0.1042
Epoch 350/500
10/10   0s 5ms/step - loss:
0.0183 - mean_absolute_error: 0.1041 - val_loss: 0.0175 -
val_mean_absolute_error: 0.1034
Epoch 351/500
10/10   0s 7ms/step - loss:
0.0182 - mean_absolute_error: 0.1039 - val_loss: 0.0175 -
val_mean_absolute_error: 0.1037
Epoch 352/500
10/10   0s 5ms/step - loss:
0.0181 - mean_absolute_error: 0.1038 - val_loss: 0.0173 -
val_mean_absolute_error: 0.1030
Epoch 353/500
10/10   0s 7ms/step - loss:
0.0181 - mean_absolute_error: 0.1036 - val_loss: 0.0172 -
val_mean_absolute_error: 0.1027
Epoch 354/500
10/10   0s 7ms/step - loss:
0.0180 - mean_absolute_error: 0.1034 - val_loss: 0.0171 -
val_mean_absolute_error: 0.1026
Epoch 355/500
10/10   0s 6ms/step - loss:
0.0179 - mean_absolute_error: 0.1032 - val_loss: 0.0170 -

val_mean_absolute_error: 0.1022
Epoch 356/500
10/10   0s 7ms/step - loss:
0.0178 - mean_absolute_error: 0.1031 - val_loss: 0.0168 -
val_mean_absolute_error: 0.1018
Epoch 357/500
10/10   0s 7ms/step - loss:
0.0177 - mean_absolute_error: 0.1029 - val_loss: 0.0167 -
val_mean_absolute_error: 0.1017
Epoch 358/500
10/10   0s 7ms/step - loss:
0.0176 - mean_absolute_error: 0.1029 - val_loss: 0.0165 -
val_mean_absolute_error: 0.1010
Epoch 359/500
10/10   0s 7ms/step - loss:
0.0175 - mean_absolute_error: 0.1027 - val_loss: 0.0165 -
val_mean_absolute_error: 0.1010
Epoch 360/500
10/10   0s 5ms/step - loss:
0.0175 - mean_absolute_error: 0.1026 - val_loss: 0.0163 -
val_mean_absolute_error: 0.1006
Epoch 361/500
10/10   0s 7ms/step - loss:
0.0174 - mean_absolute_error: 0.1024 - val_loss: 0.0162 -
val_mean_absolute_error: 0.1004
Epoch 362/500
10/10   0s 7ms/step - loss:
0.0173 - mean_absolute_error: 0.1022 - val_loss: 0.0161 -
val_mean_absolute_error: 0.1001
Epoch 363/500
10/10   0s 7ms/step - loss:
0.0172 - mean_absolute_error: 0.1021 - val_loss: 0.0160 -
val_mean_absolute_error: 0.0995
Epoch 364/500
10/10   0s 8ms/step - loss:
0.0171 - mean_absolute_error: 0.1019 - val_loss: 0.0159 -
val_mean_absolute_error: 0.0996
Epoch 365/500
10/10   0s 10ms/step -
loss: 0.0171 - mean_absolute_error: 0.1018 - val_loss: 0.0158 -
val_mean_absolute_error: 0.0991
Epoch 366/500
10/10   0s 10ms/step -
loss: 0.0170 - mean_absolute_error: 0.1016 - val_loss: 0.0157 -
val_mean_absolute_error: 0.0990
Epoch 367/500
10/10   0s 10ms/step -
loss: 0.0169 - mean_absolute_error: 0.1015 - val_loss: 0.0156 -

val_mean_absolute_error: 0.0988
Epoch 368/500
10/10   0s 15ms/step -
loss: 0.0168 - mean_absolute_error: 0.1013 - val_loss: 0.0155 -
val_mean_absolute_error: 0.0985
Epoch 369/500
10/10   0s 8ms/step - loss:
0.0167 - mean_absolute_error: 0.1012 - val_loss: 0.0154 -
val_mean_absolute_error: 0.0983
Epoch 370/500
10/10   0s 9ms/step - loss:
0.0167 - mean_absolute_error: 0.1010 - val_loss: 0.0153 -
val_mean_absolute_error: 0.0980
Epoch 371/500
10/10   0s 7ms/step - loss:
0.0166 - mean_absolute_error: 0.1009 - val_loss: 0.0152 -
val_mean_absolute_error: 0.0979
Epoch 372/500
10/10   0s 9ms/step - loss:
0.0165 - mean_absolute_error: 0.1008 - val_loss: 0.0151 -
val_mean_absolute_error: 0.0974
Epoch 373/500
10/10   0s 11ms/step -
loss: 0.0164 - mean_absolute_error: 0.1006 - val_loss: 0.0150 -
val_mean_absolute_error: 0.0973
Epoch 374/500
10/10   0s 10ms/step -
loss: 0.0164 - mean_absolute_error: 0.1005 - val_loss: 0.0149 -
val_mean_absolute_error: 0.0971
Epoch 375/500
10/10   0s 10ms/step -
loss: 0.0163 - mean_absolute_error: 0.1003 - val_loss: 0.0148 -
val_mean_absolute_error: 0.0969
Epoch 376/500
10/10   1s 41ms/step -
loss: 0.0162 - mean_absolute_error: 0.1002 - val_loss: 0.0147 -
val_mean_absolute_error: 0.0965
Epoch 377/500
10/10   0s 7ms/step - loss:
0.0162 - mean_absolute_error: 0.1000 - val_loss: 0.0146 -
val_mean_absolute_error: 0.0963
Epoch 378/500
10/10   0s 7ms/step - loss:
0.0161 - mean_absolute_error: 0.0999 - val_loss: 0.0145 -
val_mean_absolute_error: 0.0960
Epoch 379/500
10/10   0s 6ms/step - loss:
0.0160 - mean_absolute_error: 0.0997 - val_loss: 0.0145 -

val_mean_absolute_error: 0.0959
Epoch 380/500
10/10   0s 25ms/step -
loss: 0.0160 - mean_absolute_error: 0.0996 - val_loss: 0.0144 -
val_mean_absolute_error: 0.0956
Epoch 381/500
10/10   0s 7ms/step - loss:
0.0159 - mean_absolute_error: 0.0994 - val_loss: 0.0143 -
val_mean_absolute_error: 0.0953
Epoch 382/500
10/10   0s 5ms/step - loss:
0.0158 - mean_absolute_error: 0.0993 - val_loss: 0.0141 -
val_mean_absolute_error: 0.0948
Epoch 383/500
10/10   0s 5ms/step - loss:
0.0157 - mean_absolute_error: 0.0990 - val_loss: 0.0140 -
val_mean_absolute_error: 0.0944
Epoch 384/500
10/10   0s 13ms/step -
loss: 0.0157 - mean_absolute_error: 0.0990 - val_loss: 0.0139 -
val_mean_absolute_error: 0.0942
Epoch 385/500
10/10   0s 7ms/step - loss:
0.0156 - mean_absolute_error: 0.0988 - val_loss: 0.0139 -
val_mean_absolute_error: 0.0940
Epoch 386/500
10/10   0s 7ms/step - loss:
0.0156 - mean_absolute_error: 0.0986 - val_loss: 0.0138 -
val_mean_absolute_error: 0.0937
Epoch 387/500
10/10   0s 7ms/step - loss:
0.0155 - mean_absolute_error: 0.0984 - val_loss: 0.0138 -
val_mean_absolute_error: 0.0938
Epoch 388/500
10/10   0s 7ms/step - loss:
0.0154 - mean_absolute_error: 0.0983 - val_loss: 0.0136 -
val_mean_absolute_error: 0.0931
Epoch 389/500
10/10   0s 5ms/step - loss:
0.0153 - mean_absolute_error: 0.0981 - val_loss: 0.0136 -
val_mean_absolute_error: 0.0932
Epoch 390/500
10/10   0s 5ms/step - loss:
0.0153 - mean_absolute_error: 0.0979 - val_loss: 0.0135 -
val_mean_absolute_error: 0.0929
Epoch 391/500
10/10   0s 6ms/step - loss:
0.0152 - mean_absolute_error: 0.0977 - val_loss: 0.0134 -

val_mean_absolute_error: 0.0926
Epoch 392/500
10/10   0s 5ms/step - loss:
0.0152 - mean_absolute_error: 0.0976 - val_loss: 0.0134 -
val_mean_absolute_error: 0.0924
Epoch 393/500
10/10   0s 7ms/step - loss:
0.0151 - mean_absolute_error: 0.0974 - val_loss: 0.0133 -
val_mean_absolute_error: 0.0921
Epoch 394/500
10/10   0s 7ms/step - loss:
0.0150 - mean_absolute_error: 0.0972 - val_loss: 0.0133 -
val_mean_absolute_error: 0.0920
Epoch 395/500
10/10   0s 5ms/step - loss:
0.0150 - mean_absolute_error: 0.0971 - val_loss: 0.0131 -
val_mean_absolute_error: 0.0915
Epoch 396/500
10/10   0s 5ms/step - loss:
0.0149 - mean_absolute_error: 0.0969 - val_loss: 0.0131 -
val_mean_absolute_error: 0.0912
Epoch 397/500
10/10   0s 5ms/step - loss:
0.0149 - mean_absolute_error: 0.0968 - val_loss: 0.0130 -
val_mean_absolute_error: 0.0910
Epoch 398/500
10/10   0s 5ms/step - loss:
0.0148 - mean_absolute_error: 0.0966 - val_loss: 0.0129 -
val_mean_absolute_error: 0.0906
Epoch 399/500
10/10   0s 6ms/step - loss:
0.0147 - mean_absolute_error: 0.0964 - val_loss: 0.0129 -
val_mean_absolute_error: 0.0905
Epoch 400/500
10/10   0s 6ms/step - loss:
0.0147 - mean_absolute_error: 0.0963 - val_loss: 0.0128 -
val_mean_absolute_error: 0.0900
Epoch 401/500
10/10   0s 8ms/step - loss:
0.0146 - mean_absolute_error: 0.0961 - val_loss: 0.0128 -
val_mean_absolute_error: 0.0901
Epoch 402/500
10/10   0s 5ms/step - loss:
0.0146 - mean_absolute_error: 0.0960 - val_loss: 0.0127 -
val_mean_absolute_error: 0.0898
Epoch 403/500
10/10   0s 7ms/step - loss:
0.0145 - mean_absolute_error: 0.0958 - val_loss: 0.0126 -

val_mean_absolute_error: 0.0894
Epoch 404/500
10/10   0s 5ms/step - loss:
0.0145 - mean_absolute_error: 0.0956 - val_loss: 0.0126 -
val_mean_absolute_error: 0.0897
Epoch 405/500
10/10   0s 7ms/step - loss:
0.0144 - mean_absolute_error: 0.0955 - val_loss: 0.0125 -
val_mean_absolute_error: 0.0890
Epoch 406/500
10/10   0s 8ms/step - loss:
0.0144 - mean_absolute_error: 0.0954 - val_loss: 0.0125 -
val_mean_absolute_error: 0.0891
Epoch 407/500
10/10   0s 7ms/step - loss:
0.0143 - mean_absolute_error: 0.0952 - val_loss: 0.0125 -
val_mean_absolute_error: 0.0891
Epoch 408/500
10/10   0s 5ms/step - loss:
0.0143 - mean_absolute_error: 0.0951 - val_loss: 0.0124 -
val_mean_absolute_error: 0.0885
Epoch 409/500
10/10   0s 8ms/step - loss:
0.0142 - mean_absolute_error: 0.0949 - val_loss: 0.0124 -
val_mean_absolute_error: 0.0889
Epoch 410/500
10/10   0s 8ms/step - loss:
0.0142 - mean_absolute_error: 0.0948 - val_loss: 0.0123 -
val_mean_absolute_error: 0.0885
Epoch 411/500
10/10   0s 6ms/step - loss:
0.0141 - mean_absolute_error: 0.0947 - val_loss: 0.0123 -
val_mean_absolute_error: 0.0884
Epoch 412/500
10/10   0s 5ms/step - loss:
0.0141 - mean_absolute_error: 0.0946 - val_loss: 0.0122 -
val_mean_absolute_error: 0.0881
Epoch 413/500
10/10   0s 7ms/step - loss:
0.0140 - mean_absolute_error: 0.0944 - val_loss: 0.0122 -
val_mean_absolute_error: 0.0883
Epoch 414/500
10/10   0s 5ms/step - loss:
0.0140 - mean_absolute_error: 0.0943 - val_loss: 0.0122 -
val_mean_absolute_error: 0.0879
Epoch 415/500
10/10   0s 6ms/step - loss:
0.0140 - mean_absolute_error: 0.0942 - val_loss: 0.0121 -

val_mean_absolute_error: 0.0879
Epoch 416/500
10/10   0s 7ms/step - loss:
0.0139 - mean_absolute_error: 0.0941 - val_loss: 0.0121 -
val_mean_absolute_error: 0.0877
Epoch 417/500
10/10   0s 5ms/step - loss:
0.0139 - mean_absolute_error: 0.0940 - val_loss: 0.0121 -
val_mean_absolute_error: 0.0876
Epoch 418/500
10/10   0s 7ms/step - loss:
0.0139 - mean_absolute_error: 0.0939 - val_loss: 0.0121 -
val_mean_absolute_error: 0.0877
Epoch 419/500
10/10   0s 6ms/step - loss:
0.0138 - mean_absolute_error: 0.0939 - val_loss: 0.0120 -
val_mean_absolute_error: 0.0874
Epoch 420/500
10/10   0s 7ms/step - loss:
0.0138 - mean_absolute_error: 0.0938 - val_loss: 0.0120 -
val_mean_absolute_error: 0.0876
Epoch 421/500
10/10   0s 6ms/step - loss:
0.0138 - mean_absolute_error: 0.0937 - val_loss: 0.0120 -
val_mean_absolute_error: 0.0872
Epoch 422/500
10/10   0s 5ms/step - loss:
0.0138 - mean_absolute_error: 0.0936 - val_loss: 0.0119 -
val_mean_absolute_error: 0.0870
Epoch 423/500
10/10   0s 5ms/step - loss:
0.0137 - mean_absolute_error: 0.0936 - val_loss: 0.0119 -
val_mean_absolute_error: 0.0869
Epoch 424/500
10/10   0s 7ms/step - loss:
0.0137 - mean_absolute_error: 0.0935 - val_loss: 0.0118 -
val_mean_absolute_error: 0.0867
Epoch 425/500
10/10   0s 5ms/step - loss:
0.0136 - mean_absolute_error: 0.0934 - val_loss: 0.0118 -
val_mean_absolute_error: 0.0867
Epoch 426/500
10/10   0s 5ms/step - loss:
0.0137 - mean_absolute_error: 0.0935 - val_loss: 0.0117 -
val_mean_absolute_error: 0.0863
Epoch 427/500
10/10   0s 6ms/step - loss:
0.0136 - mean_absolute_error: 0.0933 - val_loss: 0.0117 -

val_mean_absolute_error: 0.0863
Epoch 428/500
10/10   0s 8ms/step - loss:
0.0136 - mean_absolute_error: 0.0933 - val_loss: 0.0116 -
val_mean_absolute_error: 0.0862
Epoch 429/500
10/10   0s 5ms/step - loss:
0.0136 - mean_absolute_error: 0.0933 - val_loss: 0.0116 -
val_mean_absolute_error: 0.0859
Epoch 430/500
10/10   0s 7ms/step - loss:
0.0135 - mean_absolute_error: 0.0931 - val_loss: 0.0116 -
val_mean_absolute_error: 0.0861
Epoch 431/500
10/10   0s 6ms/step - loss:
0.0135 - mean_absolute_error: 0.0930 - val_loss: 0.0116 -
val_mean_absolute_error: 0.0858
Epoch 432/500
10/10   0s 7ms/step - loss:
0.0135 - mean_absolute_error: 0.0929 - val_loss: 0.0115 -
val_mean_absolute_error: 0.0857
Epoch 433/500
10/10   0s 7ms/step - loss:
0.0134 - mean_absolute_error: 0.0928 - val_loss: 0.0115 -
val_mean_absolute_error: 0.0856
Epoch 434/500
10/10   0s 6ms/step - loss:
0.0134 - mean_absolute_error: 0.0927 - val_loss: 0.0115 -
val_mean_absolute_error: 0.0857
Epoch 435/500
10/10   0s 8ms/step - loss:
0.0134 - mean_absolute_error: 0.0926 - val_loss: 0.0115 -
val_mean_absolute_error: 0.0854
Epoch 436/500
10/10   0s 7ms/step - loss:
0.0133 - mean_absolute_error: 0.0925 - val_loss: 0.0115 -
val_mean_absolute_error: 0.0855
Epoch 437/500
10/10   0s 6ms/step - loss:
0.0133 - mean_absolute_error: 0.0925 - val_loss: 0.0114 -
val_mean_absolute_error: 0.0852
Epoch 438/500
10/10   0s 6ms/step - loss:
0.0133 - mean_absolute_error: 0.0923 - val_loss: 0.0114 -
val_mean_absolute_error: 0.0854
Epoch 439/500
10/10   0s 7ms/step - loss:
0.0133 - mean_absolute_error: 0.0923 - val_loss: 0.0114 -

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val_mean_absolute_error: 0.0851
Epoch 440/500
10/10              0s 7ms/step - loss:
0.0132 - mean_absolute_error: 0.0922 - val_loss: 0.0114 -
val_mean_absolute_error: 0.0850
Epoch 441/500
10/10              0s 6ms/step - loss:
0.0132 - mean_absolute_error: 0.0921 - val_loss: 0.0114 -
val_mean_absolute_error: 0.0852
Epoch 442/500
10/10              0s 7ms/step - loss:
0.0132 - mean_absolute_error: 0.0920 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0848
Epoch 443/500
10/10              0s 7ms/step - loss:
0.0132 - mean_absolute_error: 0.0919 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0848
Epoch 444/500
10/10              0s 6ms/step - loss:
0.0131 - mean_absolute_error: 0.0918 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0848
Epoch 445/500
10/10              0s 7ms/step - loss:
0.0131 - mean_absolute_error: 0.0917 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0849
Epoch 446/500
10/10              0s 7ms/step - loss:
0.0131 - mean_absolute_error: 0.0917 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0847
Epoch 447/500
10/10              0s 7ms/step - loss:
0.0131 - mean_absolute_error: 0.0916 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0847
Epoch 448/500
10/10              0s 5ms/step - loss:
0.0131 - mean_absolute_error: 0.0916 - val_loss: 0.0113 -
val_mean_absolute_error: 0.0848
Epoch 449/500
10/10              0s 6ms/step - loss:
0.0130 - mean_absolute_error: 0.0915 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0846
Epoch 450/500
10/10              0s 5ms/step - loss:
0.0130 - mean_absolute_error: 0.0914 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0845
Epoch 451/500
10/10              0s 11ms/step -
loss: 0.0130 - mean_absolute_error: 0.0914 - val_loss: 0.0112 -
```

val_mean_absolute_error: 0.0846
Epoch 452/500
10/10   0s 10ms/step -
loss: 0.0130 - mean_absolute_error: 0.0913 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0845
Epoch 453/500
10/10   0s 10ms/step -
loss: 0.0130 - mean_absolute_error: 0.0913 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0844
Epoch 454/500
10/10   0s 10ms/step -
loss: 0.0130 - mean_absolute_error: 0.0912 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0844
Epoch 455/500
10/10   0s 8ms/step - loss:
0.0129 - mean_absolute_error: 0.0912 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0844
Epoch 456/500
10/10   0s 10ms/step -
loss: 0.0129 - mean_absolute_error: 0.0912 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0843
Epoch 457/500
10/10   0s 11ms/step -
loss: 0.0129 - mean_absolute_error: 0.0911 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0842
Epoch 458/500
10/10   0s 10ms/step -
loss: 0.0129 - mean_absolute_error: 0.0910 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0843
Epoch 459/500
10/10   0s 9ms/step - loss:
0.0129 - mean_absolute_error: 0.0910 - val_loss: 0.0112 -
val_mean_absolute_error: 0.0842
Epoch 460/500
10/10   0s 11ms/step -
loss: 0.0129 - mean_absolute_error: 0.0910 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0841
Epoch 461/500
10/10   0s 9ms/step - loss:
0.0129 - mean_absolute_error: 0.0909 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0841
Epoch 462/500
10/10   0s 10ms/step -
loss: 0.0128 - mean_absolute_error: 0.0909 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0842
Epoch 463/500
10/10   0s 8ms/step - loss:
0.0128 - mean_absolute_error: 0.0908 - val_loss: 0.0111 -

val_mean_absolute_error: 0.0841
Epoch 464/500
10/10   0s 9ms/step - loss:
0.0128 - mean_absolute_error: 0.0908 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0840
Epoch 465/500
10/10   0s 8ms/step - loss:
0.0128 - mean_absolute_error: 0.0908 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0840
Epoch 466/500
10/10   0s 6ms/step - loss:
0.0128 - mean_absolute_error: 0.0907 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0841
Epoch 467/500
10/10   0s 8ms/step - loss:
0.0128 - mean_absolute_error: 0.0907 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0840
Epoch 468/500
10/10   0s 7ms/step - loss:
0.0128 - mean_absolute_error: 0.0907 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0840
Epoch 469/500
10/10   0s 6ms/step - loss:
0.0128 - mean_absolute_error: 0.0907 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0838
Epoch 470/500
10/10   0s 6ms/step - loss:
0.0128 - mean_absolute_error: 0.0906 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0840
Epoch 471/500
10/10   0s 8ms/step - loss:
0.0128 - mean_absolute_error: 0.0906 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0838
Epoch 472/500
10/10   0s 5ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0837
Epoch 473/500
10/10   0s 5ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0839
Epoch 474/500
10/10   0s 7ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0838
Epoch 475/500
10/10   0s 9ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0110 -

val_mean_absolute_error: 0.0837
Epoch 476/500
10/10   0s 7ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0837
Epoch 477/500
10/10   0s 6ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0111 -
val_mean_absolute_error: 0.0838
Epoch 478/500
10/10   0s 6ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0110 -
val_mean_absolute_error: 0.0836
Epoch 479/500
10/10   0s 7ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0110 -
val_mean_absolute_error: 0.0836
Epoch 480/500
10/10   0s 5ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0110 -
val_mean_absolute_error: 0.0835
Epoch 481/500
10/10   0s 5ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0110 -
val_mean_absolute_error: 0.0837
Epoch 482/500
10/10   0s 5ms/step - loss:
0.0127 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0838
Epoch 483/500
10/10   0s 7ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0837
Epoch 484/500
10/10   0s 8ms/step - loss:
0.0127 - mean_absolute_error: 0.0905 - val_loss: 0.0110 -
val_mean_absolute_error: 0.0838
Epoch 485/500
10/10   0s 7ms/step - loss:
0.0127 - mean_absolute_error: 0.0904 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0835
Epoch 486/500
10/10   0s 7ms/step - loss:
0.0126 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0837
Epoch 487/500
10/10   0s 5ms/step - loss:
0.0126 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -

val_mean_absolute_error: 0.0836
Epoch 488/500
10/10   0s 6ms/step - loss:
0.0126 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0835
Epoch 489/500
10/10   0s 6ms/step - loss:
0.0126 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0837
Epoch 490/500
10/10   0s 5ms/step - loss:
0.0126 - mean_absolute_error: 0.0903 - val_loss: 0.0109 -
val_mean_absolute_error: 0.0836
Epoch 491/500
10/10   0s 7ms/step - loss:
0.0126 - mean_absolute_error: 0.0902 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0834
Epoch 492/500
10/10   0s 7ms/step - loss:
0.0126 - mean_absolute_error: 0.0902 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0835
Epoch 493/500
10/10   0s 7ms/step - loss:
0.0126 - mean_absolute_error: 0.0901 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0835
Epoch 494/500
10/10   0s 5ms/step - loss:
0.0126 - mean_absolute_error: 0.0901 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0835
Epoch 495/500
10/10   0s 7ms/step - loss:
0.0126 - mean_absolute_error: 0.0901 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0835
Epoch 496/500
10/10   0s 5ms/step - loss:
0.0125 - mean_absolute_error: 0.0901 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0833
Epoch 497/500
10/10   0s 7ms/step - loss:
0.0125 - mean_absolute_error: 0.0901 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0833
Epoch 498/500
10/10   0s 7ms/step - loss:
0.0125 - mean_absolute_error: 0.0900 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0834
Epoch 499/500
10/10   0s 5ms/step - loss:
0.0125 - mean_absolute_error: 0.0900 - val_loss: 0.0107 -

```
val_mean_absolute_error: 0.0832
Epoch 500/500
10/10                  0s 5ms/step - loss:
0.0125 - mean_absolute_error: 0.0900 - val_loss: 0.0108 -
val_mean_absolute_error: 0.0833
```

1.7 Plotting Loss Curves

The following code plots the loss curves (Training loss and validation loss) with each epoch. The loss curve can be used to check whether your model converged correctly.

Run the below cell and make sure your loss curves appear to be as the ones on the right of the below image. For more reading, refer to this.

```python
[12]: import matplotlib.pyplot as plt

      # Ensure the SKIP value is appropriate for the number of epochs
      SKIP = 0   # Adjust this value based on your needs; set to 0 to include all␣
       ↪epochs

      # Plot training and validation loss
      loss = history.history['loss']
      val_loss = history.history['val_loss']
      epochs = range(1, len(loss) + 1)

      plt.figure()
      plt.plot(epochs[SKIP:], loss[SKIP:], 'g-', label='Training loss')  # Changed '.
       ↪' to '-'
      plt.plot(epochs[SKIP:], val_loss[SKIP:], 'b-', label='Validation loss')  #␣
       ↪Changed '.' to '-'
      plt.title('Training and Validation Loss')
      plt.xlabel('Epochs')
      plt.ylabel('Loss')
      plt.legend()
      plt.show()

      plt.clf()

      # Print available keys to identify correct MAE metric names
      print("Available metrics in history:", history.history.keys())

      # Check and use the correct keys for MAE metrics
      mae_key = 'mean_absolute_error'   # Replace with the correct key if different
      val_mae_key = 'val_mean_absolute_error'   # Replace with the correct key if␣
       ↪different

      mae = history.history.get(mae_key)
      val_mae = history.history.get(val_mae_key)
```

```python
if mae is not None and val_mae is not None:
    plt.figure()
    plt.plot(epochs[SKIP:], mae[SKIP:], 'g-', label='Training MAE')  # Changed␣
↪'.' to '-'
    plt.plot(epochs[SKIP:], val_mae[SKIP:], 'b-', label='Validation MAE')  #␣
↪Changed '.' to '-'
    plt.title('Training and Validation Mean Absolute Error')
    plt.xlabel('Epochs')
    plt.ylabel('MAE')
    plt.legend()
    plt.show()
else:
    print("Mean Absolute Error metrics are not available in the history.")
```
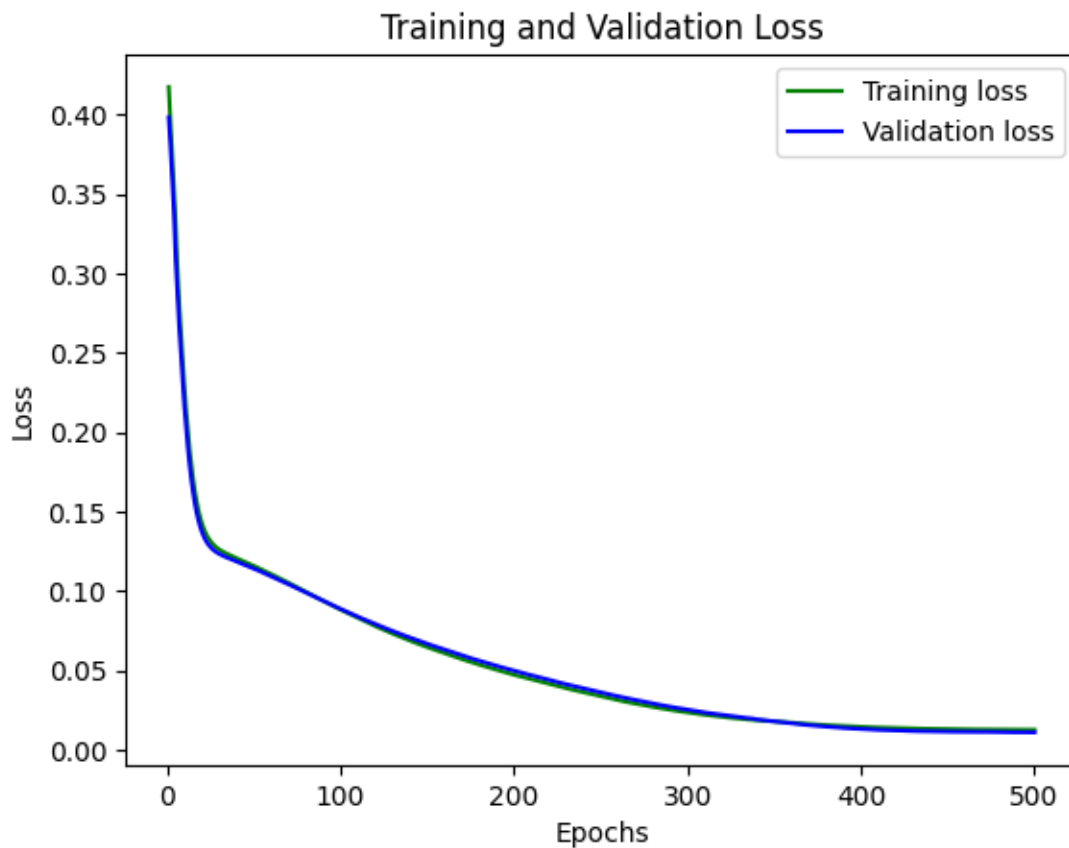

Available metrics in history: dict_keys(['loss', 'mean_absolute_error',
'val_loss', 'val_mean_absolute_error'])

<Figure size 640x480 with 0 Axes>

50

Training and Validation Mean Absolute Error
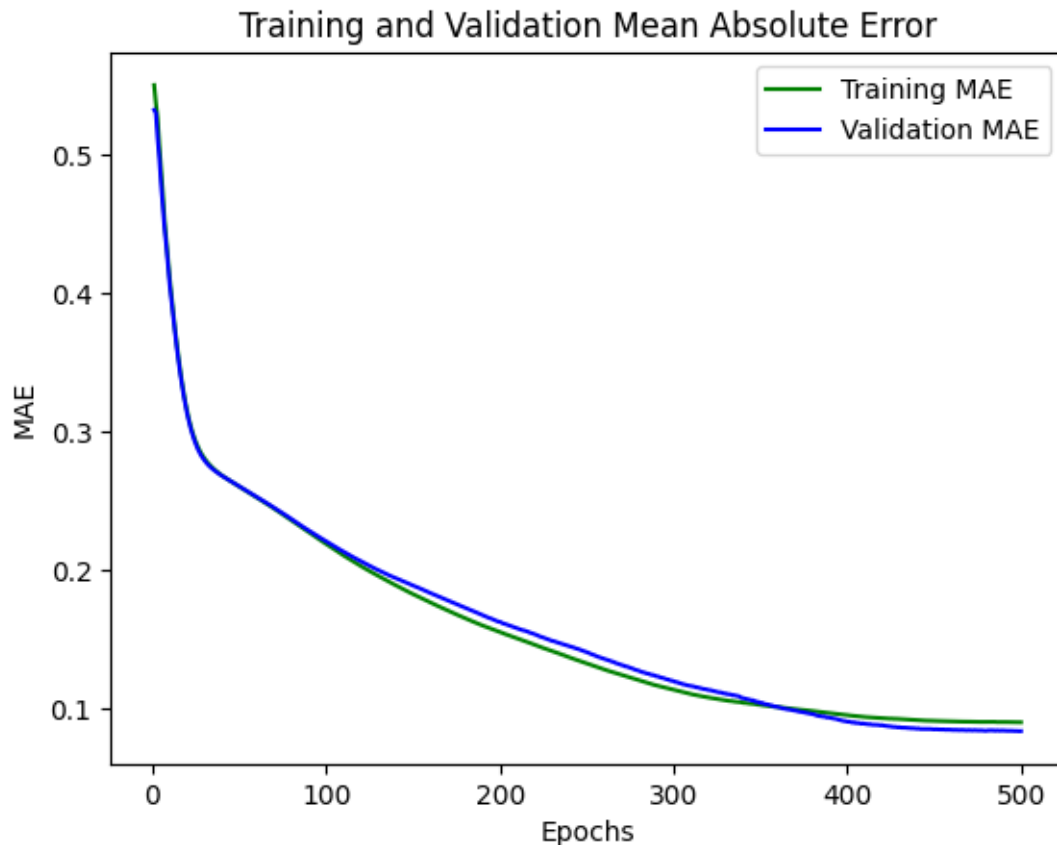
1.8 Predict using model (Graded)

Use `model.predict()` to predict values for all data in test set and plot it against true values. You may refer to this documentation for more information.

1.8.1 Exercise 5

Predict y values for test data and plot it with true values.

```python
# Make predictions based on our test dataset (TODO)
predictions = model.predict(x_test)

# Graph the predictions against the actual values
plt.clf()
plt.title('Comparison of predictions and actual values')
plt.plot(x_test, y_test, 'b.', label='Actual')
plt.plot(x_test, predictions, 'r.', label='Predicted')
plt.legend()
plt.show()
```

7/7　　　　　　　0s 2ms/step

Comparison of predictions and actual values
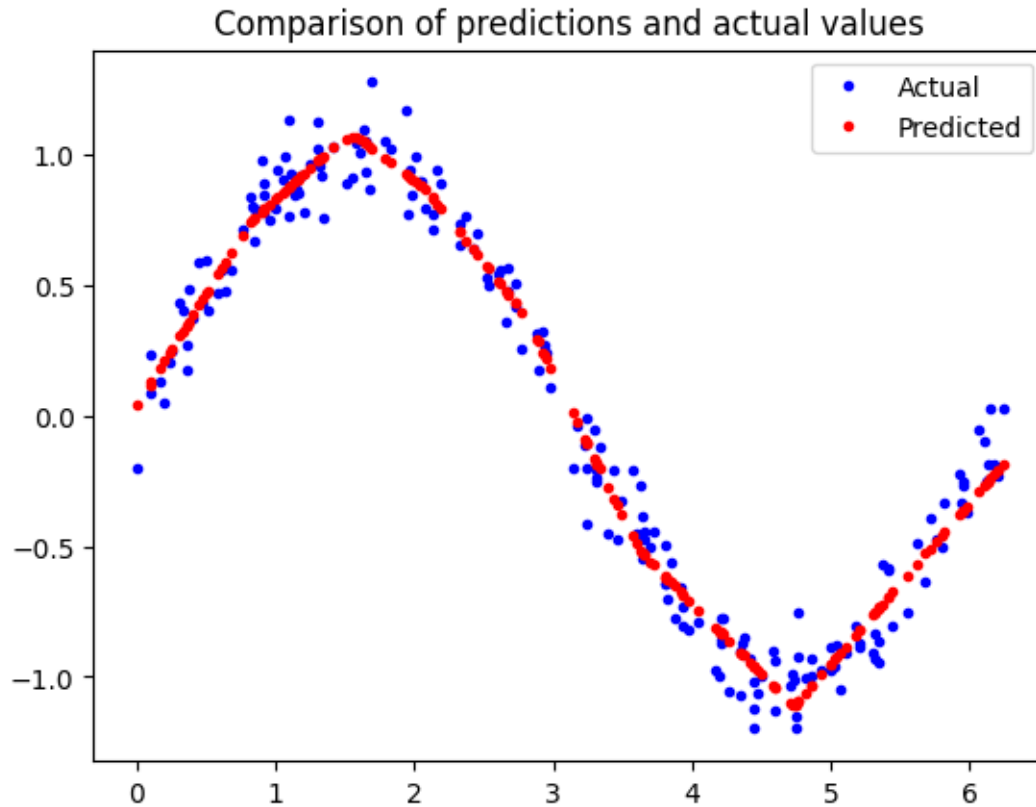
1.8.2 Exercise 6

The predicted graph is not nearly as smooth enough to be a sine. Rather it may look like a piecewise combination of linear functions. Briefly explain how you can make this more smoother and identical to an actual sine wave.

1.9 Get weights

Now you will extract the weight matrices from the model. This step is in order to convert these weight matrices to C++ files that will be embedded in the Microcontroller.

```
[14]: # Extract weights and biases as Numpy arrays
W1, b1 = model.layers[0].get_weights()
W2, b2 = model.layers[1].get_weights()
W3, b3 = model.layers[2].get_weights()
```

```
[15]: print(W1.shape, b1.shape)
print(W2.shape, b2.shape)
print(W3.shape, b3.shape)
```

```
(1, 16) (16,)
(16, 16) (16,)
```

```
(16, 1) (1,)
```

The following code performs the forward propagation of the model manually using NumPy matrix multiplication. Run the following code to make sure the model's prediction and manual prediction is same.

```
[16]: xs = x_test
```

```
[17]: # This is what the TF model does internally:
      ys = []
      for x in xs:
          x = np.array([x])        # x should be array
          h1 = x @ W1 + b1         # dense layer
          h1 = np.maximum(0, h1)   # ReLU
          h2 = h1 @ W2 + b2        # dense layer
          h2 = np.maximum(0, h2)   # ReLU
          h3 = h2 @ W3 + b3        # dense layer
          ys.append(h3)

      ys = np.stack(ys)
```

```
[18]: # Are our predictions the same as TF's predictions?
      # This should print 0 if the results are close enough.
      print(np.sum(np.abs(ys - predictions) > 1e-6))  # Should print 0 if they are␣
        ↪close enough
```

```
0
```

1.10 Export the weights for C++

The following code compresses the weights and biases into a C++ format which will be stored in the Microcontroller's FLASH memory. Copy the generated output and paste in file named `model_data.cpp`.

```
[19]: # Note that we transpose W2. This makes the inner loop for the
      # matrix multiplication a little simpler.

      names = ["W1_data", "b1_data", "W2_data", "b2_data", "W3_data", "b3_data"]
      arrays = [W1, b1, W2.T, b2, W3, b3]
```

```
[20]: # Copy this into model_data.cpp:

      for name, array in zip(names, arrays):
          print("const float %s[] PROGMEM = {" % name)
          print("   ", ", ".join([str(x) + "f" for x in array.flatten()]))
          print("};\n")
```

```
const float W1_data[] PROGMEM = {
     -0.20968106f, -0.40894282f, 0.5666974f, 0.022080446f, -0.21071774f,
```

```
0.2559584f, -0.33475357f, -0.4573499f, 0.138243f, -0.54041797f, 0.20992972f,
-0.36495143f, -0.05582869f, 0.65957916f, 0.478987f, -0.46314204f
};

const float b1_data[] PROGMEM = {
    0.0f, 0.0f, 0.273521f, 0.1544416f, 0.0f, 0.5817219f, 0.0f, 0.0f,
-0.28991345f, 0.0f, -0.58686364f, 0.0f, 0.0f, -0.9741869f, -0.0052238577f, 0.0f
};

const float W2_data[] PROGMEM = {
    -0.18758528f, -0.22891311f, -0.22634149f, 0.4542626f, -0.15429527f,
-0.15280572f, 0.25078556f, -0.30672795f, 0.20584628f, -0.055847555f,
0.020724684f, 0.09618804f, -0.25379714f, -0.38036627f, 0.032453615f,
-0.20054199f, -0.35586986f, -0.2903623f, 0.188046f, -0.09561993f, -0.33890307f,
0.3740042f, 0.41879204f, -0.0085635185f, -0.5470803f, -0.4132978f, -0.70695686f,
0.40479222f, -0.3315459f, -0.0772111f, -0.058975525f, 0.07553324f, 0.37238708f,
0.25920042f, 0.39414722f, 0.038809408f, -0.23379762f, -0.2428089f, -0.12219304f,
-0.291514f, 0.0055889357f, -0.07026696f, -0.1562905f, 0.22360232f, 0.16956916f,
-0.024426458f, -0.16049288f, 0.26063743f, -0.21799959f, 0.31507763f,
-0.10872558f, 0.1071303f, 0.2945064f, -0.14089063f, 0.35750714f, -0.22563024f,
-0.043110322f, -0.21326466f, 0.32838297f, -0.41752583f, -0.28789118f, 0.515146f,
0.022169698f, 0.15594253f, 0.21426585f, 0.40259925f, 0.2549173f, -0.08716445f,
0.13983306f, -0.10688259f, -0.006031275f, 0.31573197f, -0.058936495f,
0.005013764f, 0.56817937f, -0.21953815f, -0.078240454f, -0.34131393f, 0.309488f,
0.11079016f, -0.12414464f, 0.15962866f, -0.30287275f, -0.04866971f,
-0.27044308f, -0.23898059f, -0.14819905f, 0.11507586f, 0.027522713f,
0.12736854f, -0.15008584f, -0.027891785f, -0.21314986f, 0.11567631f,
0.065696836f, 0.010568917f, -0.0022000074f, -0.106233f, -0.040252402f,
1.2846621f, -0.24345979f, 0.1869714f, 0.016486436f, 0.225027f, -1.4330664f,
0.02340576f, -1.4156458f, -0.1269682f, -0.20534329f, -0.4131778f, 0.27153555f,
0.3292546f, 0.058782518f, 0.37531242f, 0.15823773f, 0.092986375f, 0.13870022f,
-0.19583175f, 0.38021758f, 0.34247157f, -0.03069821f, 0.36163643f, -0.36274737f,
-0.31005105f, 0.006929755f, 0.20951268f, -0.3457657f, -0.40500292f,
-0.18815856f, 0.24497113f, 0.102571756f, -0.07253623f, -0.054793715f,
-0.2732648f, 0.32003346f, 0.36654118f, -0.10793914f, 0.24130294f, 0.6757123f,
0.11692706f, -0.06050703f, 0.22912297f, 0.09234148f, -0.12964672f, -0.1721273f,
-0.39352363f, -0.546682f, 1.0149297f, -0.084426105f, -0.3242273f, -0.06472999f,
-0.07997611f, -0.41416377f, 0.29936644f, -0.3857146f, -0.4174519f,
-0.0040114224f, -0.42960584f, -0.25126305f, 0.17109194f, -0.36406988f,
0.30584863f, -0.2655251f, -0.2652632f, 0.35896465f, -0.09222305f, 0.27089855f,
-0.1696788f, 0.03318131f, -0.13557631f, -0.19838205f, 0.0041693747f,
0.119853824f, -0.18919414f, 0.10358897f, -0.3408388f, -0.3593464f, -0.2895845f,
0.03887826f, 0.16183141f, -0.04975331f, -0.07636961f, 0.10157904f, 0.26257083f,
-0.3310544f, 0.044127345f, 0.17332104f, 0.09151378f, 0.10695353f, -0.12709779f,
-0.37406585f, 0.091709465f, 0.09091833f, -0.057093352f, 0.25187382f,
0.016445965f, 0.029577047f, -0.2417546f, -0.05560723f, 0.37250802f,
-0.40214124f, 0.34706673f, 0.22655115f, -0.01640457f, 0.12767693f, -0.39703128f,
-0.2791188f, -0.15115383f, 0.06847152f, 0.39015117f, 0.23234396f, -0.0790708f,
```

```
0.09399834f, -0.035793148f, 0.12441626f, 0.34999582f, -0.5446116f, -0.33358204f,
-0.27041948f, -0.16236344f, 0.32114258f, -0.09587371f, 0.14005204f,
0.036981195f, 0.056573838f, 0.2904617f, -0.060356952f, 0.07144933f, 0.28198984f,
0.5030623f, 0.20299909f, -0.2552371f, -0.5937036f, -0.09314942f, 0.022862121f,
-0.41940972f, -0.23086905f, 0.24883012f, -0.22440585f, -0.038752437f,
-0.29262197f, -0.10032377f, -0.5240493f, 0.8353018f, -0.38593677f, -0.17584181f,
-0.32296214f, 0.08162722f, 0.2676246f, 0.2962604f, -0.16980311f, 0.114295095f,
0.31481078f, 0.19480985f, 0.2602575f, -0.09033328f
};

const float b2_data[] PROGMEM = {
    0.33784807f, 0.34394097f, 0.35071144f, -0.37502357f, -0.19616312f,
-0.008929323f, 0.8233431f, 0.0f, -0.38381377f, 0.58109576f, 0.0f, -0.030111626f,
0.0f, 0.29232752f, 0.31004778f, 0.41635254f
};

const float W3_data[] PROGMEM = {
    -1.0708604f, -0.73693174f, -0.56750137f, 1.0077977f, 0.18526728f,
0.29116082f, 1.9769284f, 0.06886464f, 0.7573859f, -0.8690804f, 0.5337312f,
0.36677316f, -0.03215623f, -0.4938473f, -0.3103817f, -0.907731f
};

const float b3_data[] PROGMEM = {
    -0.30734932f
};
```

1.11   End of Section 1