

arduino-tinymml-workshop

February 27, 2025

Tiny ML on Arduino ## Gesture recognition tutorial * Sandeep Mistry - Arduino * Don Coleman - Chariot Solutions

<https://github.com/arduino/ArduinoTensorFlowLiteTutorials/>

0.1 Setup Python Environment

The next cell sets up the dependencies in required for the notebook, run it.

```
[1]: # Setup environment
!apt-get -qq install xxd
!pip install pandas numpy matplotlib
!pip install tensorflow
```

Requirement already satisfied: pandas in /usr/local/lib/python3.11/dist-packages (2.2.2)

Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (1.26.4)

Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-packages (3.10.0)

Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.11/dist-packages (from pandas) (2.8.2)

Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages (from pandas) (2025.1)

Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-packages (from pandas) (2025.1)

Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (1.3.1)

Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (4.56.0)

Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (1.4.8)

Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (24.2)

Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.11/dist-packages (from matplotlib) (11.1.0)

Requirement already satisfied: pyparsing>=2.3.1 in

/usr/local/lib/python3.11/dist-packages (from matplotlib) (3.2.1)
 Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.8.2->pandas) (1.17.0)
 Requirement already satisfied: tensorflow in /usr/local/lib/python3.11/dist-packages (2.18.0)
 Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.4.0)
 Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.6.3)
 Requirement already satisfied: flatbuffers>=24.3.25 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (25.2.10)
 Requirement already satisfied: gast!=0.5.0,!0.5.1,!0.5.2,>=0.2.1 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.6.0)
 Requirement already satisfied: google-pasta>=0.1.1 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.2.0)
 Requirement already satisfied: libclang>=13.0.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (18.1.1)
 Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.4.0)
 Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-packages (from tensorflow) (24.2)
 Requirement already satisfied: protobuf!=4.21.0,!4.21.1,!4.21.2,!4.21.3,!4.21.4,!4.21.5,<6.0.0dev,>=3.20.3 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (4.25.6)
 Requirement already satisfied: requests<3,>=2.21.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.32.3)
 Requirement already satisfied: setuptools in /usr/local/lib/python3.11/dist-packages (from tensorflow) (75.1.0)
 Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.17.0)
 Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.5.0)
 Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (4.12.2)
 Requirement already satisfied: wrapt>=1.11.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.17.2)
 Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.70.0)
 Requirement already satisfied: tensorboard<2.19,>=2.18 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.18.0)
 Requirement already satisfied: keras>=3.5.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.8.0)
 Requirement already satisfied: numpy<2.1.0,>=1.26.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.26.4)
 Requirement already satisfied: h5py>=3.11.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.12.1)
 Requirement already satisfied: ml-dtypes<0.5.0,>=0.4.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.4.1)

Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.37.1)

Requirement already satisfied: wheel<1.0,>=0.23.0 in /usr/local/lib/python3.11/dist-packages (from astunparse>=1.6.0->tensorflow) (0.45.1)

Requirement already satisfied: rich in /usr/local/lib/python3.11/dist-packages (from keras>=3.5.0->tensorflow) (13.9.4)

Requirement already satisfied: namex in /usr/local/lib/python3.11/dist-packages (from keras>=3.5.0->tensorflow) (0.0.8)

Requirement already satisfied: optree in /usr/local/lib/python3.11/dist-packages (from keras>=3.5.0->tensorflow) (0.14.0)

Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/dist-packages (from requests<3,>=2.21.0->tensorflow) (3.4.1)

Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-packages (from requests<3,>=2.21.0->tensorflow) (3.10)

Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.11/dist-packages (from requests<3,>=2.21.0->tensorflow) (2.3.0)

Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.11/dist-packages (from requests<3,>=2.21.0->tensorflow) (2025.1.31)

Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18->tensorflow) (3.7)

Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18->tensorflow) (0.7.2)

Requirement already satisfied: werkzeug>=1.0.1 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18->tensorflow) (3.1.3)

Requirement already satisfied: MarkupSafe>=2.1.1 in /usr/local/lib/python3.11/dist-packages (from werkzeug>=1.0.1->tensorboard<2.19,>=2.18->tensorflow) (3.0.2)

Requirement already satisfied: markdown-it-py>=2.2.0 in /usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0->tensorflow) (3.0.0)

Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0->tensorflow) (2.18.0)

Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-packages (from markdown-it-py>=2.2.0->rich->keras>=3.5.0->tensorflow) (0.1.2)

1 Upload Data

1. Open the panel on the left side of Colab by clicking on the >
2. Select the files tab

3. Drag `punch.csv` and `flex.csv` files from your computer to the tab to upload them into colab.

2 Graph Data (optional)

We'll graph the input files on two separate graphs, acceleration and gyroscope, as each data set has different units and scale.

```
[2]: import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

filename = "punch.csv"

df = pd.read_csv("/content/" + filename)

index = range(1, len(df['aX']) + 1)

plt.rcParams["figure.figsize"] = (20,10)

plt.plot(index, df['aX'], 'g.', label='x', linestyle='solid', marker=',')
plt.plot(index, df['aY'], 'b.', label='y', linestyle='solid', marker=',')
plt.plot(index, df['aZ'], 'r.', label='z', linestyle='solid', marker=',')
plt.title("Acceleration")
plt.xlabel("Sample #")
plt.ylabel("Acceleration (G)")
plt.legend()
plt.show()

plt.plot(index, df['gX'], 'g.', label='x', linestyle='solid', marker=',')
plt.plot(index, df['gY'], 'b.', label='y', linestyle='solid', marker=',')
plt.plot(index, df['gZ'], 'r.', label='z', linestyle='solid', marker=',')
plt.title("Gyroscope")
plt.xlabel("Sample #")
plt.ylabel("Gyroscope (deg/sec)")
plt.legend()
plt.show()
```

<ipython-input-2-91e50062f3c0>:13: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "g." (-> marker='.'). The keyword argument will take precedence.

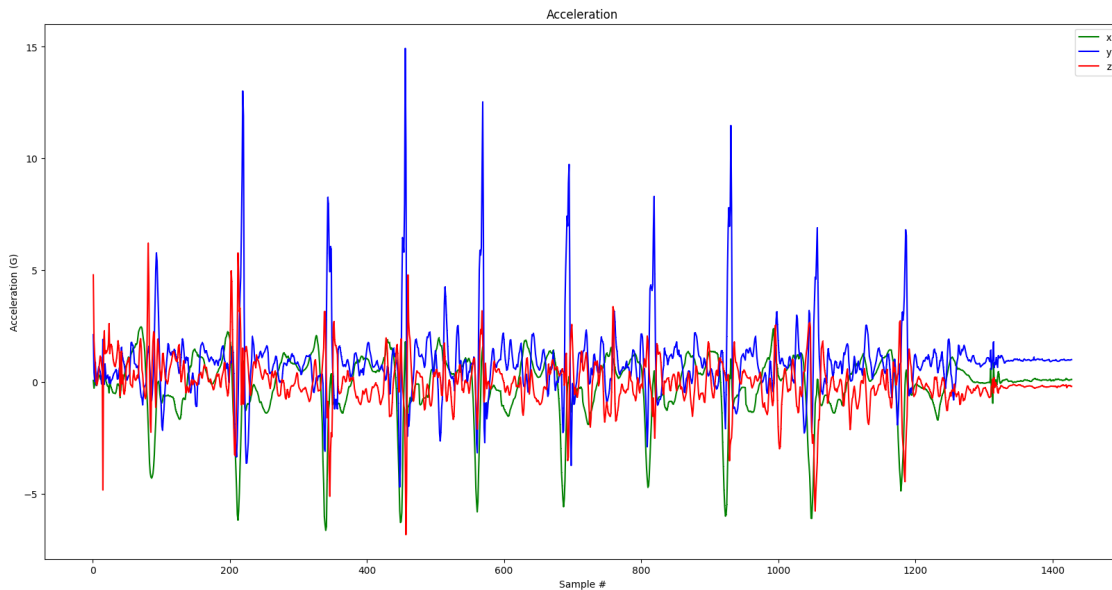
```
plt.plot(index, df['aX'], 'g.', label='x', linestyle='solid', marker=',')
```

<ipython-input-2-91e50062f3c0>:14: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "b." (-> marker='.'). The keyword argument will take precedence.

```
plt.plot(index, df['aY'], 'b.', label='y', linestyle='solid', marker=',')
```

<ipython-input-2-91e50062f3c0>:15: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "r." (-> marker='.'). The keyword argument will take precedence.

```
plt.plot(index, df['aZ'], 'r.', label='z', linestyle='solid', marker=',')
```



<ipython-input-2-91e50062f3c0>:22: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "g." (-> marker='.'). The keyword argument will take precedence.

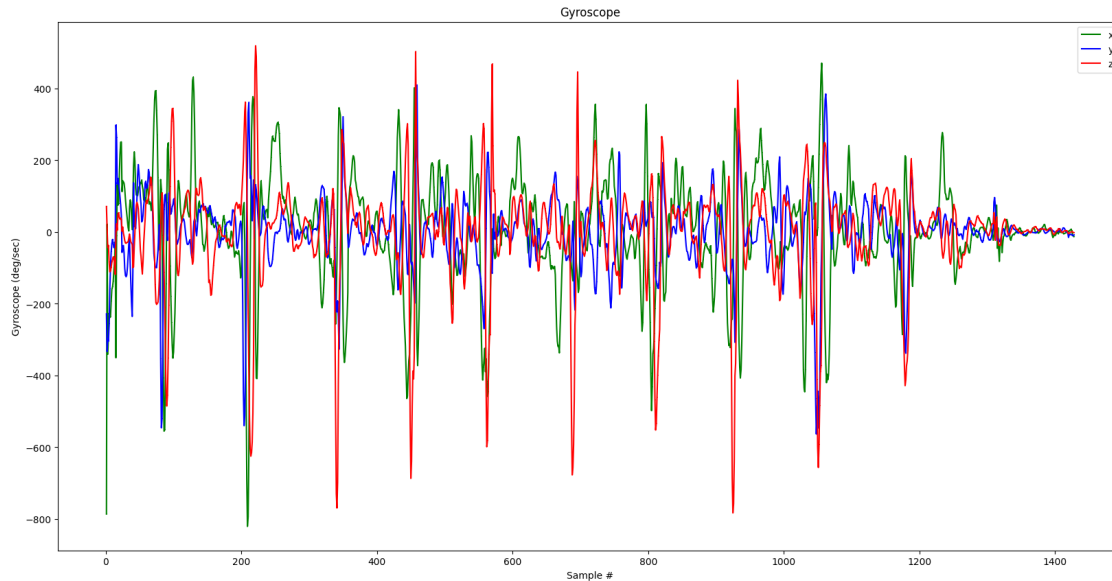
```
plt.plot(index, df['gX'], 'g.', label='x', linestyle='solid', marker=',')
```

<ipython-input-2-91e50062f3c0>:23: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "b." (-> marker='.'). The keyword argument will take precedence.

```
plt.plot(index, df['gY'], 'b.', label='y', linestyle='solid', marker=',')
```

<ipython-input-2-91e50062f3c0>:24: UserWarning: marker is redundantly defined by the 'marker' keyword argument and the fmt string "r." (-> marker='.'). The keyword argument will take precedence.

```
plt.plot(index, df['gZ'], 'r.', label='z', linestyle='solid', marker=',')
```



3 Train Neural Network

3.1 Parse and prepare the data

The next cell parses the csv files and transforms them to a format that will be used to train the fully connected neural network.

Update the `GESTURES` list with the gesture data you've collected in `.csv` format.

```
[3]: import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import tensorflow as tf

print(f"TensorFlow version = {tf.__version__}\n")

# Set a fixed random seed value, for reproducibility, this will allow us to get
# the same random numbers each time the notebook is run
SEED = 1337
np.random.seed(SEED)
tf.random.set_seed(SEED)

# the list of gestures that data is available for
GESTURES = [
    "punch",
    "flex",
]
```

```

SAMPLES_PER_GESTURE = 119

NUM_GESTURES = len(GESTURES)

# create a one-hot encoded matrix that is used in the output
ONE_HOT_ENCODED_GESTURES = np.eye(NUM_GESTURES)

inputs = []
outputs = []

# read each csv file and push an input and output
for gesture_index in range(NUM_GESTURES):
    gesture = GESTURES[gesture_index]
    print(f"Processing index {gesture_index} for gesture '{gesture}'.")

    output = ONE_HOT_ENCODED_GESTURES[gesture_index]

    df = pd.read_csv("/content/" + gesture + ".csv")

    # calculate the number of gesture recordings in the file
    num_recordings = int(df.shape[0] / SAMPLES_PER_GESTURE)

    print(f"\tThere are {num_recordings} recordings of the {gesture} gesture.")

    for i in range(num_recordings):
        tensor = []
        for j in range(SAMPLES_PER_GESTURE):
            index = i * SAMPLES_PER_GESTURE + j
            # normalize the input data, between 0 to 1:
            # - acceleration is between: -4 to +4
            # - gyroscope is between: -2000 to +2000
            tensor += [
                (df['aX'][index] + 4) / 8,
                (df['aY'][index] + 4) / 8,
                (df['aZ'][index] + 4) / 8,
                (df['gX'][index] + 2000) / 4000,
                (df['gY'][index] + 2000) / 4000,
                (df['gZ'][index] + 2000) / 4000
            ]

        inputs.append(tensor)
        outputs.append(output)

# convert the list to numpy array
inputs = np.array(inputs)
outputs = np.array(outputs)

```

```
print("Data set parsing and preparation complete.")
```

TensorFlow version = 2.18.0

Processing index 0 for gesture 'punch'.

There are 12 recordings of the punch gesture.

Processing index 1 for gesture 'flex'.

There are 17 recordings of the flex gesture.

Data set parsing and preparation complete.

3.2 Randomize and split the input and output pairs for training

Randomly split input and output pairs into sets of data: 60% for training, 20% for validation, and 20% for testing.

- the training set is used to train the model
- the validation set is used to measure how well the model is performing during training
- the testing set is used to test the model after training

```
[4]: # Randomize the order of the inputs, so they can be evenly distributed for
      ↪ training, testing, and validation
      # https://stackoverflow.com/a/37710486/2020087
      num_inputs = len(inputs)
      randomize = np.arange(num_inputs)
      np.random.shuffle(randomize)

      # Swap the consecutive indexes (0, 1, 2, etc) with the randomized indexes
      inputs = inputs[randomize]
      outputs = outputs[randomize]

      # Split the recordings (group of samples) into three sets: training, testing,
      ↪ and validation
      TRAIN_SPLIT = int(0.6 * num_inputs)
      TEST_SPLIT = int(0.2 * num_inputs + TRAIN_SPLIT)

      inputs_train, inputs_test, inputs_validate = np.split(inputs, [TRAIN_SPLIT,
      ↪ TEST_SPLIT])
      outputs_train, outputs_test, outputs_validate = np.split(outputs, [TRAIN_SPLIT,
      ↪ TEST_SPLIT])

      print("Data set randomization and splitting complete.")
```

Data set randomization and splitting complete.

3.3 Build & Train the Model

Build and train a [TensorFlow](#) model using the high-level [Keras](#) API.


```
[5]: # build the model and train it
model = tf.keras.Sequential()
model.add(tf.keras.layers.Dense(50, activation='relu')) # relu is used for
↳performance
model.add(tf.keras.layers.Dense(15, activation='relu'))
model.add(tf.keras.layers.Dense(NUM_GESTURES, activation='softmax')) # softmax
↳is used, because we only expect one gesture to occur per input
model.compile(optimizer='rmsprop', loss='mse', metrics=['mae'])
history = model.fit(inputs_train, outputs_train, epochs=600, batch_size=1,
↳validation_data=(inputs_validate, outputs_validate))
```

```
Epoch 1/600
17/17          2s 21ms/step -
loss: 0.3507 - mae: 0.5684 - val_loss: 0.2042 - val_mae: 0.3973
Epoch 2/600
17/17          0s 8ms/step - loss:
0.3287 - mae: 0.5481 - val_loss: 0.2032 - val_mae: 0.4182
Epoch 3/600
17/17          0s 16ms/step -
loss: 0.3139 - mae: 0.5410 - val_loss: 0.2015 - val_mae: 0.4190
Epoch 4/600
17/17          1s 9ms/step - loss:
0.2950 - mae: 0.5251 - val_loss: 0.2000 - val_mae: 0.4153
Epoch 5/600
17/17          0s 14ms/step -
loss: 0.3005 - mae: 0.5303 - val_loss: 0.2000 - val_mae: 0.4224
Epoch 6/600
17/17          1s 35ms/step -
loss: 0.2885 - mae: 0.5230 - val_loss: 0.1955 - val_mae: 0.4103
Epoch 7/600
17/17          1s 29ms/step -
loss: 0.2900 - mae: 0.5195 - val_loss: 0.1922 - val_mae: 0.4041
Epoch 8/600
17/17          0s 21ms/step -
loss: 0.2897 - mae: 0.5178 - val_loss: 0.1915 - val_mae: 0.4065
Epoch 9/600
17/17          1s 27ms/step -
loss: 0.2831 - mae: 0.5124 - val_loss: 0.1883 - val_mae: 0.4042
Epoch 10/600
17/17          1s 28ms/step -
loss: 0.2768 - mae: 0.5071 - val_loss: 0.1866 - val_mae: 0.3977
Epoch 11/600
17/17          0s 9ms/step - loss:
0.2797 - mae: 0.5074 - val_loss: 0.1815 - val_mae: 0.3948
Epoch 12/600
17/17          0s 14ms/step -
loss: 0.2727 - mae: 0.5014 - val_loss: 0.1777 - val_mae: 0.3898
```

Epoch 13/600
17/17 0s 17ms/step -
loss: 0.2632 - mae: 0.4922 - val_loss: 0.1765 - val_mae: 0.3809
Epoch 14/600
17/17 1s 22ms/step -
loss: 0.2670 - mae: 0.4919 - val_loss: 0.1726 - val_mae: 0.3753
Epoch 15/600
17/17 1s 35ms/step -
loss: 0.2636 - mae: 0.4876 - val_loss: 0.1690 - val_mae: 0.3705
Epoch 16/600
17/17 0s 21ms/step -
loss: 0.2594 - mae: 0.4826 - val_loss: 0.1656 - val_mae: 0.3660
Epoch 17/600
17/17 0s 16ms/step -
loss: 0.2517 - mae: 0.4737 - val_loss: 0.1632 - val_mae: 0.3611
Epoch 18/600
17/17 1s 23ms/step -
loss: 0.2509 - mae: 0.4720 - val_loss: 0.1578 - val_mae: 0.3542
Epoch 19/600
17/17 1s 24ms/step -
loss: 0.2471 - mae: 0.4670 - val_loss: 0.1549 - val_mae: 0.3517
Epoch 20/600
17/17 1s 32ms/step -
loss: 0.2421 - mae: 0.4611 - val_loss: 0.1519 - val_mae: 0.3494
Epoch 21/600
17/17 0s 9ms/step - loss:
0.2341 - mae: 0.4533 - val_loss: 0.1467 - val_mae: 0.3391
Epoch 22/600
17/17 0s 10ms/step -
loss: 0.2294 - mae: 0.4458 - val_loss: 0.1423 - val_mae: 0.3317
Epoch 23/600
17/17 0s 8ms/step - loss:
0.2238 - mae: 0.4386 - val_loss: 0.1341 - val_mae: 0.3092
Epoch 24/600
17/17 0s 9ms/step - loss:
0.2140 - mae: 0.4232 - val_loss: 0.1280 - val_mae: 0.2969
Epoch 25/600
17/17 0s 9ms/step - loss:
0.2063 - mae: 0.4126 - val_loss: 0.1224 - val_mae: 0.2901
Epoch 26/600
17/17 0s 9ms/step - loss:
0.1996 - mae: 0.4051 - val_loss: 0.1167 - val_mae: 0.2828
Epoch 27/600
17/17 0s 5ms/step - loss:
0.1905 - mae: 0.3942 - val_loss: 0.1122 - val_mae: 0.2754
Epoch 28/600
17/17 0s 4ms/step - loss:
0.1829 - mae: 0.3844 - val_loss: 0.1077 - val_mae: 0.2722

Epoch 29/600
17/17 0s 7ms/step - loss:
0.1750 - mae: 0.3745 - val_loss: 0.1029 - val_mae: 0.2623
Epoch 30/600
17/17 0s 8ms/step - loss:
0.1685 - mae: 0.3650 - val_loss: 0.0978 - val_mae: 0.2552
Epoch 31/600
17/17 0s 7ms/step - loss:
0.1601 - mae: 0.3542 - val_loss: 0.0930 - val_mae: 0.2497
Epoch 32/600
17/17 0s 8ms/step - loss:
0.1527 - mae: 0.3443 - val_loss: 0.0884 - val_mae: 0.2417
Epoch 33/600
17/17 0s 8ms/step - loss:
0.1458 - mae: 0.3340 - val_loss: 0.0834 - val_mae: 0.2326
Epoch 34/600
17/17 0s 6ms/step - loss:
0.1386 - mae: 0.3238 - val_loss: 0.0787 - val_mae: 0.2250
Epoch 35/600
17/17 0s 8ms/step - loss:
0.1316 - mae: 0.3131 - val_loss: 0.0741 - val_mae: 0.2177
Epoch 36/600
17/17 0s 8ms/step - loss:
0.1241 - mae: 0.3020 - val_loss: 0.0699 - val_mae: 0.2103
Epoch 37/600
17/17 0s 8ms/step - loss:
0.1183 - mae: 0.2925 - val_loss: 0.0654 - val_mae: 0.2026
Epoch 38/600
17/17 0s 8ms/step - loss:
0.1119 - mae: 0.2823 - val_loss: 0.0613 - val_mae: 0.1945
Epoch 39/600
17/17 0s 10ms/step -
loss: 0.1061 - mae: 0.2726 - val_loss: 0.0573 - val_mae: 0.1876
Epoch 40/600
17/17 0s 6ms/step - loss:
0.1004 - mae: 0.2631 - val_loss: 0.0536 - val_mae: 0.1805
Epoch 41/600
17/17 0s 8ms/step - loss:
0.0948 - mae: 0.2533 - val_loss: 0.0500 - val_mae: 0.1732
Epoch 42/600
17/17 0s 8ms/step - loss:
0.0900 - mae: 0.2446 - val_loss: 0.0464 - val_mae: 0.1666
Epoch 43/600
17/17 0s 4ms/step - loss:
0.0843 - mae: 0.2348 - val_loss: 0.0433 - val_mae: 0.1600
Epoch 44/600
17/17 0s 4ms/step - loss:
0.0798 - mae: 0.2262 - val_loss: 0.0402 - val_mae: 0.1531

Epoch 45/600
17/17 0s 4ms/step - loss:
0.0751 - mae: 0.2170 - val_loss: 0.0372 - val_mae: 0.1472
Epoch 46/600
17/17 0s 5ms/step - loss:
0.0709 - mae: 0.2089 - val_loss: 0.0344 - val_mae: 0.1404
Epoch 47/600
17/17 0s 4ms/step - loss:
0.0671 - mae: 0.2009 - val_loss: 0.0317 - val_mae: 0.1342
Epoch 48/600
17/17 0s 4ms/step - loss:
0.0629 - mae: 0.1921 - val_loss: 0.0293 - val_mae: 0.1288
Epoch 49/600
17/17 0s 4ms/step - loss:
0.0593 - mae: 0.1843 - val_loss: 0.0270 - val_mae: 0.1234
Epoch 50/600
17/17 0s 4ms/step - loss:
0.0556 - mae: 0.1763 - val_loss: 0.0250 - val_mae: 0.1186
Epoch 51/600
17/17 0s 6ms/step - loss:
0.0526 - mae: 0.1692 - val_loss: 0.0230 - val_mae: 0.1138
Epoch 52/600
17/17 0s 6ms/step - loss:
0.0497 - mae: 0.1622 - val_loss: 0.0212 - val_mae: 0.1093
Epoch 53/600
17/17 0s 8ms/step - loss:
0.0471 - mae: 0.1557 - val_loss: 0.0196 - val_mae: 0.1052
Epoch 54/600
17/17 0s 6ms/step - loss:
0.0450 - mae: 0.1500 - val_loss: 0.0181 - val_mae: 0.1013
Epoch 55/600
17/17 0s 5ms/step - loss:
0.0432 - mae: 0.1446 - val_loss: 0.0168 - val_mae: 0.0976
Epoch 56/600
17/17 0s 8ms/step - loss:
0.0416 - mae: 0.1397 - val_loss: 0.0155 - val_mae: 0.0941
Epoch 57/600
17/17 0s 5ms/step - loss:
0.0400 - mae: 0.1349 - val_loss: 0.0144 - val_mae: 0.0909
Epoch 58/600
17/17 0s 5ms/step - loss:
0.0389 - mae: 0.1311 - val_loss: 0.0134 - val_mae: 0.0877
Epoch 59/600
17/17 0s 8ms/step - loss:
0.0379 - mae: 0.1273 - val_loss: 0.0124 - val_mae: 0.0849
Epoch 60/600
17/17 0s 5ms/step - loss:
0.0371 - mae: 0.1240 - val_loss: 0.0116 - val_mae: 0.0821

Epoch 61/600
17/17 0s 6ms/step - loss:
0.0364 - mae: 0.1209 - val_loss: 0.0108 - val_mae: 0.0794
Epoch 62/600
17/17 0s 5ms/step - loss:
0.0358 - mae: 0.1181 - val_loss: 0.0101 - val_mae: 0.0770
Epoch 63/600
17/17 0s 5ms/step - loss:
0.0354 - mae: 0.1156 - val_loss: 0.0095 - val_mae: 0.0746
Epoch 64/600
17/17 0s 5ms/step - loss:
0.0349 - mae: 0.1131 - val_loss: 0.0088 - val_mae: 0.0723
Epoch 65/600
17/17 0s 5ms/step - loss:
0.0346 - mae: 0.1110 - val_loss: 0.0083 - val_mae: 0.0701
Epoch 66/600
17/17 0s 6ms/step - loss:
0.0343 - mae: 0.1090 - val_loss: 0.0078 - val_mae: 0.0681
Epoch 67/600
17/17 0s 8ms/step - loss:
0.0340 - mae: 0.1070 - val_loss: 0.0073 - val_mae: 0.0661
Epoch 68/600
17/17 0s 8ms/step - loss:
0.0338 - mae: 0.1051 - val_loss: 0.0069 - val_mae: 0.0642
Epoch 69/600
17/17 0s 5ms/step - loss:
0.0335 - mae: 0.1032 - val_loss: 0.0065 - val_mae: 0.0625
Epoch 70/600
17/17 0s 5ms/step - loss:
0.0333 - mae: 0.1017 - val_loss: 0.0061 - val_mae: 0.0607
Epoch 71/600
17/17 0s 7ms/step - loss:
0.0330 - mae: 0.1000 - val_loss: 0.0058 - val_mae: 0.0592
Epoch 72/600
17/17 0s 5ms/step - loss:
0.0328 - mae: 0.0985 - val_loss: 0.0055 - val_mae: 0.0576
Epoch 73/600
17/17 0s 6ms/step - loss:
0.0325 - mae: 0.0970 - val_loss: 0.0052 - val_mae: 0.0561
Epoch 74/600
17/17 0s 7ms/step - loss:
0.0325 - mae: 0.0958 - val_loss: 0.0049 - val_mae: 0.0547
Epoch 75/600
17/17 0s 7ms/step - loss:
0.0321 - mae: 0.0942 - val_loss: 0.0047 - val_mae: 0.0533
Epoch 76/600
17/17 0s 7ms/step - loss:
0.0319 - mae: 0.0930 - val_loss: 0.0044 - val_mae: 0.0520

Epoch 77/600
17/17 0s 6ms/step - loss:
0.0317 - mae: 0.0917 - val_loss: 0.0042 - val_mae: 0.0507
Epoch 78/600
17/17 0s 10ms/step -
loss: 0.0314 - mae: 0.0905 - val_loss: 0.0040 - val_mae: 0.0495
Epoch 79/600
17/17 0s 8ms/step - loss:
0.0312 - mae: 0.0893 - val_loss: 0.0038 - val_mae: 0.0484
Epoch 80/600
17/17 0s 8ms/step - loss:
0.0310 - mae: 0.0882 - val_loss: 0.0036 - val_mae: 0.0472
Epoch 81/600
17/17 0s 11ms/step -
loss: 0.0308 - mae: 0.0871 - val_loss: 0.0035 - val_mae: 0.0462
Epoch 82/600
17/17 0s 5ms/step - loss:
0.0307 - mae: 0.0861 - val_loss: 0.0033 - val_mae: 0.0452
Epoch 83/600
17/17 0s 7ms/step - loss:
0.0302 - mae: 0.0849 - val_loss: 0.0032 - val_mae: 0.0442
Epoch 84/600
17/17 0s 5ms/step - loss:
0.0300 - mae: 0.0840 - val_loss: 0.0031 - val_mae: 0.0433
Epoch 85/600
17/17 0s 5ms/step - loss:
0.0297 - mae: 0.0829 - val_loss: 0.0030 - val_mae: 0.0424
Epoch 86/600
17/17 0s 5ms/step - loss:
0.0293 - mae: 0.0819 - val_loss: 0.0028 - val_mae: 0.0416
Epoch 87/600
17/17 0s 5ms/step - loss:
0.0290 - mae: 0.0809 - val_loss: 0.0027 - val_mae: 0.0408
Epoch 88/600
17/17 0s 5ms/step - loss:
0.0286 - mae: 0.0799 - val_loss: 0.0027 - val_mae: 0.0400
Epoch 89/600
17/17 0s 5ms/step - loss:
0.0282 - mae: 0.0789 - val_loss: 0.0026 - val_mae: 0.0393
Epoch 90/600
17/17 0s 7ms/step - loss:
0.0278 - mae: 0.0780 - val_loss: 0.0025 - val_mae: 0.0385
Epoch 91/600
17/17 0s 8ms/step - loss:
0.0274 - mae: 0.0770 - val_loss: 0.0024 - val_mae: 0.0378
Epoch 92/600
17/17 0s 5ms/step - loss:
0.0270 - mae: 0.0761 - val_loss: 0.0023 - val_mae: 0.0372

Epoch 93/600
17/17 0s 6ms/step - loss:
0.0266 - mae: 0.0752 - val_loss: 0.0023 - val_mae: 0.0365
Epoch 94/600
17/17 0s 8ms/step - loss:
0.0262 - mae: 0.0743 - val_loss: 0.0022 - val_mae: 0.0359
Epoch 95/600
17/17 0s 5ms/step - loss:
0.0257 - mae: 0.0733 - val_loss: 0.0021 - val_mae: 0.0353
Epoch 96/600
17/17 0s 7ms/step - loss:
0.0253 - mae: 0.0724 - val_loss: 0.0021 - val_mae: 0.0347
Epoch 97/600
17/17 0s 8ms/step - loss:
0.0249 - mae: 0.0716 - val_loss: 0.0020 - val_mae: 0.0342
Epoch 98/600
17/17 0s 5ms/step - loss:
0.0244 - mae: 0.0707 - val_loss: 0.0020 - val_mae: 0.0336
Epoch 99/600
17/17 0s 5ms/step - loss:
0.0239 - mae: 0.0698 - val_loss: 0.0019 - val_mae: 0.0331
Epoch 100/600
17/17 0s 6ms/step - loss:
0.0234 - mae: 0.0688 - val_loss: 0.0019 - val_mae: 0.0326
Epoch 101/600
17/17 0s 8ms/step - loss:
0.0230 - mae: 0.0679 - val_loss: 0.0019 - val_mae: 0.0321
Epoch 102/600
17/17 0s 5ms/step - loss:
0.0224 - mae: 0.0670 - val_loss: 0.0018 - val_mae: 0.0316
Epoch 103/600
17/17 0s 5ms/step - loss:
0.0222 - mae: 0.0663 - val_loss: 0.0018 - val_mae: 0.0312
Epoch 104/600
17/17 0s 6ms/step - loss:
0.0216 - mae: 0.0654 - val_loss: 0.0018 - val_mae: 0.0308
Epoch 105/600
17/17 0s 5ms/step - loss:
0.0211 - mae: 0.0644 - val_loss: 0.0017 - val_mae: 0.0304
Epoch 106/600
17/17 0s 5ms/step - loss:
0.0206 - mae: 0.0635 - val_loss: 0.0017 - val_mae: 0.0299
Epoch 107/600
17/17 0s 7ms/step - loss:
0.0200 - mae: 0.0626 - val_loss: 0.0017 - val_mae: 0.0296
Epoch 108/600
17/17 0s 8ms/step - loss:
0.0195 - mae: 0.0617 - val_loss: 0.0016 - val_mae: 0.0290

Epoch 109/600
17/17 0s 4ms/step - loss:
0.0189 - mae: 0.0607 - val_loss: 0.0016 - val_mae: 0.0285
Epoch 110/600
17/17 0s 4ms/step - loss:
0.0185 - mae: 0.0598 - val_loss: 0.0016 - val_mae: 0.0282
Epoch 111/600
17/17 0s 5ms/step - loss:
0.0180 - mae: 0.0590 - val_loss: 0.0015 - val_mae: 0.0278
Epoch 112/600
17/17 0s 5ms/step - loss:
0.0175 - mae: 0.0581 - val_loss: 0.0015 - val_mae: 0.0274
Epoch 113/600
17/17 0s 7ms/step - loss:
0.0169 - mae: 0.0570 - val_loss: 0.0015 - val_mae: 0.0269
Epoch 114/600
17/17 0s 4ms/step - loss:
0.0165 - mae: 0.0562 - val_loss: 0.0014 - val_mae: 0.0266
Epoch 115/600
17/17 0s 4ms/step - loss:
0.0159 - mae: 0.0553 - val_loss: 0.0014 - val_mae: 0.0263
Epoch 116/600
17/17 0s 4ms/step - loss:
0.0154 - mae: 0.0543 - val_loss: 0.0014 - val_mae: 0.0260
Epoch 117/600
17/17 0s 4ms/step - loss:
0.0149 - mae: 0.0534 - val_loss: 0.0014 - val_mae: 0.0255
Epoch 118/600
17/17 0s 4ms/step - loss:
0.0143 - mae: 0.0523 - val_loss: 0.0013 - val_mae: 0.0251
Epoch 119/600
17/17 0s 4ms/step - loss:
0.0139 - mae: 0.0515 - val_loss: 0.0013 - val_mae: 0.0248
Epoch 120/600
17/17 0s 5ms/step - loss:
0.0134 - mae: 0.0505 - val_loss: 0.0013 - val_mae: 0.0245
Epoch 121/600
17/17 0s 5ms/step - loss:
0.0129 - mae: 0.0495 - val_loss: 0.0013 - val_mae: 0.0242
Epoch 122/600
17/17 0s 4ms/step - loss:
0.0124 - mae: 0.0486 - val_loss: 0.0012 - val_mae: 0.0237
Epoch 123/600
17/17 0s 4ms/step - loss:
0.0119 - mae: 0.0475 - val_loss: 0.0012 - val_mae: 0.0232
Epoch 124/600
17/17 0s 4ms/step - loss:
0.0116 - mae: 0.0467 - val_loss: 0.0011 - val_mae: 0.0229

Epoch 125/600
17/17 0s 4ms/step - loss:
0.0111 - mae: 0.0457 - val_loss: 0.0011 - val_mae: 0.0226
Epoch 126/600
17/17 0s 5ms/step - loss:
0.0106 - mae: 0.0447 - val_loss: 0.0011 - val_mae: 0.0223
Epoch 127/600
17/17 0s 4ms/step - loss:
0.0102 - mae: 0.0438 - val_loss: 0.0010 - val_mae: 0.0217
Epoch 128/600
17/17 0s 5ms/step - loss:
0.0097 - mae: 0.0427 - val_loss: 0.0010 - val_mae: 0.0212
Epoch 129/600
17/17 0s 5ms/step - loss:
0.0094 - mae: 0.0419 - val_loss: 9.8612e-04 - val_mae: 0.0209
Epoch 130/600
17/17 0s 4ms/step - loss:
0.0089 - mae: 0.0409 - val_loss: 9.6120e-04 - val_mae: 0.0206
Epoch 131/600
17/17 0s 4ms/step - loss:
0.0085 - mae: 0.0400 - val_loss: 9.3786e-04 - val_mae: 0.0202
Epoch 132/600
17/17 0s 5ms/step - loss:
0.0081 - mae: 0.0390 - val_loss: 9.1383e-04 - val_mae: 0.0199
Epoch 133/600
17/17 0s 5ms/step - loss:
0.0078 - mae: 0.0381 - val_loss: 8.6195e-04 - val_mae: 0.0193
Epoch 134/600
17/17 0s 4ms/step - loss:
0.0074 - mae: 0.0370 - val_loss: 8.2314e-04 - val_mae: 0.0188
Epoch 135/600
17/17 0s 5ms/step - loss:
0.0071 - mae: 0.0363 - val_loss: 8.0357e-04 - val_mae: 0.0185
Epoch 136/600
17/17 0s 4ms/step - loss:
0.0067 - mae: 0.0353 - val_loss: 7.7859e-04 - val_mae: 0.0182
Epoch 137/600
17/17 0s 5ms/step - loss:
0.0064 - mae: 0.0344 - val_loss: 7.5569e-04 - val_mae: 0.0178
Epoch 138/600
17/17 0s 4ms/step - loss:
0.0061 - mae: 0.0335 - val_loss: 7.1188e-04 - val_mae: 0.0173
Epoch 139/600
17/17 0s 4ms/step - loss:
0.0057 - mae: 0.0325 - val_loss: 6.7711e-04 - val_mae: 0.0168
Epoch 140/600
17/17 0s 4ms/step - loss:
0.0055 - mae: 0.0317 - val_loss: 6.5400e-04 - val_mae: 0.0165

Epoch 141/600
17/17 0s 4ms/step - loss:
0.0052 - mae: 0.0308 - val_loss: 6.3019e-04 - val_mae: 0.0161

Epoch 142/600
17/17 0s 4ms/step - loss:
0.0049 - mae: 0.0299 - val_loss: 6.0857e-04 - val_mae: 0.0158

Epoch 143/600
17/17 0s 4ms/step - loss:
0.0046 - mae: 0.0290 - val_loss: 5.7257e-04 - val_mae: 0.0152

Epoch 144/600
17/17 0s 4ms/step - loss:
0.0043 - mae: 0.0281 - val_loss: 6.0025e-04 - val_mae: 0.0154

Epoch 145/600
17/17 0s 4ms/step - loss:
0.0038 - mae: 0.0263 - val_loss: 5.3788e-04 - val_mae: 0.0146

Epoch 146/600
17/17 0s 5ms/step - loss:
0.0037 - mae: 0.0261 - val_loss: 4.7528e-04 - val_mae: 0.0138

Epoch 147/600
17/17 0s 4ms/step - loss:
0.0038 - mae: 0.0260 - val_loss: 4.7630e-04 - val_mae: 0.0137

Epoch 148/600
17/17 0s 5ms/step - loss:
0.0034 - mae: 0.0247 - val_loss: 4.7969e-04 - val_mae: 0.0136

Epoch 149/600
17/17 0s 4ms/step - loss:
0.0030 - mae: 0.0233 - val_loss: 4.4313e-04 - val_mae: 0.0130

Epoch 150/600
17/17 0s 7ms/step - loss:
0.0029 - mae: 0.0227 - val_loss: 3.8575e-04 - val_mae: 0.0122

Epoch 151/600
17/17 0s 4ms/step - loss:
0.0029 - mae: 0.0228 - val_loss: 3.8819e-04 - val_mae: 0.0122

Epoch 152/600
17/17 0s 5ms/step - loss:
0.0026 - mae: 0.0215 - val_loss: 3.8200e-04 - val_mae: 0.0119

Epoch 153/600
17/17 0s 5ms/step - loss:
0.0023 - mae: 0.0202 - val_loss: 3.1514e-04 - val_mae: 0.0110

Epoch 154/600
17/17 0s 5ms/step - loss:
0.0024 - mae: 0.0205 - val_loss: 3.1710e-04 - val_mae: 0.0109

Epoch 155/600
17/17 0s 4ms/step - loss:
0.0021 - mae: 0.0192 - val_loss: 3.0661e-04 - val_mae: 0.0106

Epoch 156/600
17/17 0s 5ms/step - loss:
0.0019 - mae: 0.0182 - val_loss: 2.4182e-04 - val_mae: 0.0096

Epoch 157/600
17/17 0s 5ms/step - loss:
0.0020 - mae: 0.0188 - val_loss: 2.7009e-04 - val_mae: 0.0099

Epoch 158/600
17/17 0s 7ms/step - loss:
0.0017 - mae: 0.0173 - val_loss: 4.4818e-05 - val_mae: 0.0051

Epoch 159/600
17/17 0s 8ms/step - loss:
0.0175 - mae: 0.0453 - val_loss: 4.2978e-05 - val_mae: 0.0051

Epoch 160/600
17/17 0s 8ms/step - loss:
0.0143 - mae: 0.0401 - val_loss: 1.3896e-04 - val_mae: 0.0075

Epoch 161/600
17/17 0s 6ms/step - loss:
0.0019 - mae: 0.0162 - val_loss: 6.1215e-04 - val_mae: 0.0138

Epoch 162/600
17/17 0s 9ms/step - loss:
4.2793e-04 - mae: 0.0092 - val_loss: 2.4497e-04 - val_mae: 0.0093

Epoch 163/600
17/17 0s 6ms/step - loss:
0.0036 - mae: 0.0185 - val_loss: 7.3599e-05 - val_mae: 0.0056

Epoch 164/600
17/17 0s 4ms/step - loss:
0.0270 - mae: 0.0658 - val_loss: 6.9021e-05 - val_mae: 0.0057

Epoch 165/600
17/17 0s 4ms/step - loss:
0.0029 - mae: 0.0190 - val_loss: 8.9067e-04 - val_mae: 0.0163

Epoch 166/600
17/17 0s 5ms/step - loss:
2.2358e-04 - mae: 0.0074 - val_loss: 3.8797e-04 - val_mae: 0.0112

Epoch 167/600
17/17 0s 4ms/step - loss:
4.1447e-04 - mae: 0.0088 - val_loss: 1.8516e-04 - val_mae: 0.0081

Epoch 168/600
17/17 0s 5ms/step - loss:
7.7588e-04 - mae: 0.0117 - val_loss: 1.0066e-04 - val_mae: 0.0063

Epoch 169/600
17/17 0s 4ms/step - loss:
0.0014 - mae: 0.0148 - val_loss: 1.5386e-04 - val_mae: 0.0074

Epoch 170/600
17/17 0s 5ms/step - loss:
0.0031 - mae: 0.0166 - val_loss: 5.3641e-05 - val_mae: 0.0047

Epoch 171/600
17/17 0s 4ms/step - loss:
0.0265 - mae: 0.0634 - val_loss: 5.2993e-05 - val_mae: 0.0049

Epoch 172/600
17/17 0s 4ms/step - loss:
0.0018 - mae: 0.0150 - val_loss: 8.4810e-04 - val_mae: 0.0157

Epoch 173/600
17/17 0s 4ms/step - loss:
1.3553e-04 - mae: 0.0059 - val_loss: 3.6145e-04 - val_mae: 0.0106
Epoch 174/600
17/17 0s 5ms/step - loss:
2.3564e-04 - mae: 0.0069 - val_loss: 8.5856e-05 - val_mae: 0.0057
Epoch 175/600
17/17 0s 5ms/step - loss:
0.0010 - mae: 0.0124 - val_loss: 1.7591e-04 - val_mae: 0.0076
Epoch 176/600
17/17 0s 5ms/step - loss:
0.0016 - mae: 0.0123 - val_loss: 5.9886e-05 - val_mae: 0.0047
Epoch 177/600
17/17 0s 4ms/step - loss:
0.0131 - mae: 0.0519 - val_loss: 1.8414e-05 - val_mae: 0.0033
Epoch 178/600
17/17 0s 4ms/step - loss:
0.0138 - mae: 0.0381 - val_loss: 2.2224e-04 - val_mae: 0.0084
Epoch 179/600
17/17 0s 4ms/step - loss:
2.2211e-04 - mae: 0.0069 - val_loss: 3.5612e-04 - val_mae: 0.0104
Epoch 180/600
17/17 0s 4ms/step - loss:
1.3759e-04 - mae: 0.0057 - val_loss: 2.5211e-04 - val_mae: 0.0089
Epoch 181/600
17/17 0s 4ms/step - loss:
1.7354e-04 - mae: 0.0059 - val_loss: 4.2870e-05 - val_mae: 0.0043
Epoch 182/600
17/17 0s 5ms/step - loss:
0.0014 - mae: 0.0139 - val_loss: 5.2283e-05 - val_mae: 0.0046
Epoch 183/600
17/17 0s 5ms/step - loss:
0.0024 - mae: 0.0149 - val_loss: 3.2933e-05 - val_mae: 0.0037
Epoch 184/600
17/17 0s 5ms/step - loss:
0.0255 - mae: 0.0581 - val_loss: 5.1637e-05 - val_mae: 0.0045
Epoch 185/600
17/17 0s 5ms/step - loss:
5.9653e-04 - mae: 0.0096 - val_loss: 2.4462e-04 - val_mae: 0.0087
Epoch 186/600
17/17 0s 5ms/step - loss:
1.2900e-04 - mae: 0.0055 - val_loss: 2.7956e-04 - val_mae: 0.0092
Epoch 187/600
17/17 0s 4ms/step - loss:
1.0516e-04 - mae: 0.0050 - val_loss: 1.3807e-04 - val_mae: 0.0067
Epoch 188/600
17/17 0s 5ms/step - loss:
2.4790e-04 - mae: 0.0064 - val_loss: 1.2100e-05 - val_mae: 0.0027

Epoch 189/600
17/17 0s 4ms/step - loss:
0.0104 - mae: 0.0354 - val_loss: 1.1782e-05 - val_mae: 0.0026
Epoch 190/600
17/17 0s 4ms/step - loss:
0.0060 - mae: 0.0254 - val_loss: 6.4703e-04 - val_mae: 0.0135
Epoch 191/600
17/17 0s 4ms/step - loss:
4.2426e-05 - mae: 0.0035 - val_loss: 3.2110e-04 - val_mae: 0.0097
Epoch 192/600
17/17 0s 5ms/step - loss:
5.8324e-05 - mae: 0.0039 - val_loss: 1.5417e-04 - val_mae: 0.0069
Epoch 193/600
17/17 0s 5ms/step - loss:
9.8028e-05 - mae: 0.0045 - val_loss: 1.8494e-05 - val_mae: 0.0029
Epoch 194/600
17/17 0s 4ms/step - loss:
0.0017 - mae: 0.0147 - val_loss: 1.9820e-05 - val_mae: 0.0030
Epoch 195/600
17/17 0s 4ms/step - loss:
0.0014 - mae: 0.0128 - val_loss: 1.1327e-05 - val_mae: 0.0024
Epoch 196/600
17/17 0s 4ms/step - loss:
0.0184 - mae: 0.0450 - val_loss: 2.0761e-05 - val_mae: 0.0030
Epoch 197/600
17/17 0s 5ms/step - loss:
6.5266e-04 - mae: 0.0094 - val_loss: 1.1335e-04 - val_mae: 0.0060
Epoch 198/600
17/17 0s 4ms/step - loss:
9.0073e-05 - mae: 0.0045 - val_loss: 1.7774e-04 - val_mae: 0.0073
Epoch 199/600
17/17 0s 4ms/step - loss:
5.6729e-05 - mae: 0.0038 - val_loss: 1.3051e-04 - val_mae: 0.0063
Epoch 200/600
17/17 0s 5ms/step - loss:
6.8329e-05 - mae: 0.0039 - val_loss: 2.3781e-05 - val_mae: 0.0031
Epoch 201/600
17/17 0s 5ms/step - loss:
8.3177e-04 - mae: 0.0100 - val_loss: 9.3253e-06 - val_mae: 0.0022
Epoch 202/600
17/17 0s 5ms/step - loss:
0.0024 - mae: 0.0179 - val_loss: 7.8730e-05 - val_mae: 0.0050
Epoch 203/600
17/17 0s 4ms/step - loss:
7.7245e-05 - mae: 0.0041 - val_loss: 1.4419e-04 - val_mae: 0.0065
Epoch 204/600
17/17 0s 4ms/step - loss:
4.4238e-05 - mae: 0.0033 - val_loss: 5.9644e-05 - val_mae: 0.0044

Epoch 205/600
17/17 0s 5ms/step - loss:
1.5286e-04 - mae: 0.0048 - val_loss: 1.1891e-05 - val_mae: 0.0022

Epoch 206/600
17/17 0s 5ms/step - loss:
3.8182e-04 - mae: 0.0107 - val_loss: 8.0946e-06 - val_mae: 0.0020

Epoch 207/600
17/17 0s 4ms/step - loss:
0.0018 - mae: 0.0139 - val_loss: 7.7765e-06 - val_mae: 0.0019

Epoch 208/600
17/17 0s 5ms/step - loss:
9.6270e-04 - mae: 0.0105 - val_loss: 1.9485e-04 - val_mae: 0.0074

Epoch 209/600
17/17 0s 7ms/step - loss:
2.1482e-05 - mae: 0.0024 - val_loss: 9.7335e-05 - val_mae: 0.0054

Epoch 210/600
17/17 0s 5ms/step - loss:
2.9601e-05 - mae: 0.0027 - val_loss: 4.1542e-05 - val_mae: 0.0037

Epoch 211/600
17/17 0s 5ms/step - loss:
7.7061e-05 - mae: 0.0035 - val_loss: 3.3907e-06 - val_mae: 0.0014

Epoch 212/600
17/17 0s 4ms/step - loss:
0.0045 - mae: 0.0234 - val_loss: 5.3061e-04 - val_mae: 0.0119

Epoch 213/600
17/17 0s 5ms/step - loss:
1.2772e-05 - mae: 0.0018 - val_loss: 2.1511e-04 - val_mae: 0.0077

Epoch 214/600
17/17 0s 5ms/step - loss:
1.3755e-05 - mae: 0.0019 - val_loss: 9.4091e-05 - val_mae: 0.0052

Epoch 215/600
17/17 0s 4ms/step - loss:
1.9318e-05 - mae: 0.0022 - val_loss: 4.8400e-05 - val_mae: 0.0038

Epoch 216/600
17/17 0s 4ms/step - loss:
3.1273e-05 - mae: 0.0025 - val_loss: 3.5889e-06 - val_mae: 0.0014

Epoch 217/600
17/17 0s 4ms/step - loss:
0.0020 - mae: 0.0141 - val_loss: 4.0569e-06 - val_mae: 0.0014

Epoch 218/600
17/17 0s 4ms/step - loss:
6.6933e-04 - mae: 0.0084 - val_loss: 1.2482e-04 - val_mae: 0.0059

Epoch 219/600
17/17 0s 5ms/step - loss:
1.3358e-05 - mae: 0.0019 - val_loss: 8.5575e-05 - val_mae: 0.0049

Epoch 220/600
17/17 0s 5ms/step - loss:
1.5267e-05 - mae: 0.0020 - val_loss: 4.6549e-05 - val_mae: 0.0037

Epoch 221/600
17/17 0s 4ms/step - loss:
2.0424e-05 - mae: 0.0021 - val_loss: 1.2097e-05 - val_mae: 0.0021

Epoch 222/600
17/17 0s 5ms/step - loss:
8.5328e-05 - mae: 0.0036 - val_loss: 1.4770e-05 - val_mae: 0.0022

Epoch 223/600
17/17 0s 4ms/step - loss:
1.3177e-04 - mae: 0.0039 - val_loss: 8.2588e-06 - val_mae: 0.0016

Epoch 224/600
17/17 0s 4ms/step - loss:
6.5549e-04 - mae: 0.0123 - val_loss: 2.2313e-05 - val_mae: 0.0026

Epoch 225/600
17/17 0s 4ms/step - loss:
2.2039e-05 - mae: 0.0020 - val_loss: 1.0205e-05 - val_mae: 0.0018

Epoch 226/600
17/17 0s 5ms/step - loss:
9.1022e-05 - mae: 0.0034 - val_loss: 4.0357e-06 - val_mae: 0.0012

Epoch 227/600
17/17 0s 5ms/step - loss:
3.0163e-04 - mae: 0.0094 - val_loss: 2.5097e-05 - val_mae: 0.0027

Epoch 228/600
17/17 0s 4ms/step - loss:
1.0553e-05 - mae: 0.0015 - val_loss: 2.3219e-05 - val_mae: 0.0026

Epoch 229/600
17/17 0s 5ms/step - loss:
1.0915e-05 - mae: 0.0015 - val_loss: 8.1707e-06 - val_mae: 0.0016

Epoch 230/600
17/17 0s 4ms/step - loss:
4.1091e-05 - mae: 0.0023 - val_loss: 8.8319e-07 - val_mae: 7.0012e-04

Epoch 231/600
17/17 0s 4ms/step - loss:
0.0040 - mae: 0.0208 - val_loss: 5.8805e-04 - val_mae: 0.0123

Epoch 232/600
17/17 0s 4ms/step - loss:
6.3752e-06 - mae: 9.4090e-04 - val_loss: 2.3027e-04 - val_mae: 0.0077

Epoch 233/600
17/17 0s 4ms/step - loss:
3.6294e-06 - mae: 8.8958e-04 - val_loss: 9.4851e-05 - val_mae: 0.0050

Epoch 234/600
17/17 0s 7ms/step - loss:
3.3436e-06 - mae: 9.3193e-04 - val_loss: 4.2108e-05 - val_mae: 0.0034

Epoch 235/600
17/17 0s 5ms/step - loss:
4.5313e-06 - mae: 0.0011 - val_loss: 2.5747e-05 - val_mae: 0.0027

Epoch 236/600
17/17 0s 4ms/step - loss:
5.3268e-06 - mae: 0.0011 - val_loss: 1.8292e-05 - val_mae: 0.0023

Epoch 237/600
17/17 0s 4ms/step - loss:
5.9728e-06 - mae: 0.0011 - val_loss: 1.4721e-05 - val_mae: 0.0021

Epoch 238/600
17/17 0s 5ms/step - loss:
6.3858e-06 - mae: 0.0011 - val_loss: 1.3617e-05 - val_mae: 0.0020

Epoch 239/600
17/17 0s 4ms/step - loss:
6.0168e-06 - mae: 0.0011 - val_loss: 1.4731e-05 - val_mae: 0.0020

Epoch 240/600
17/17 0s 4ms/step - loss:
5.0528e-06 - mae: 0.0010 - val_loss: 1.6196e-05 - val_mae: 0.0021

Epoch 241/600
17/17 0s 5ms/step - loss:
4.2955e-06 - mae: 9.7390e-04 - val_loss: 1.6461e-05 - val_mae: 0.0021

Epoch 242/600
17/17 0s 4ms/step - loss:
3.9047e-06 - mae: 9.3380e-04 - val_loss: 1.4639e-05 - val_mae: 0.0020

Epoch 243/600
17/17 0s 5ms/step - loss:
3.9180e-06 - mae: 9.2660e-04 - val_loss: 1.4677e-05 - val_mae: 0.0020

Epoch 244/600
17/17 0s 5ms/step - loss:
3.6228e-06 - mae: 8.9461e-04 - val_loss: 1.4680e-05 - val_mae: 0.0020

Epoch 245/600
17/17 0s 4ms/step - loss:
3.4249e-06 - mae: 8.7294e-04 - val_loss: 1.4725e-05 - val_mae: 0.0020

Epoch 246/600
17/17 0s 4ms/step - loss:
3.2032e-06 - mae: 8.4777e-04 - val_loss: 1.4723e-05 - val_mae: 0.0020

Epoch 247/600
17/17 0s 4ms/step - loss:
3.0123e-06 - mae: 8.2482e-04 - val_loss: 1.4705e-05 - val_mae: 0.0020

Epoch 248/600
17/17 0s 4ms/step - loss:
2.8430e-06 - mae: 8.0350e-04 - val_loss: 1.4674e-05 - val_mae: 0.0020

Epoch 249/600
17/17 0s 4ms/step - loss:
2.6916e-06 - mae: 7.8365e-04 - val_loss: 1.4629e-05 - val_mae: 0.0020

Epoch 250/600
17/17 0s 5ms/step - loss:
2.5558e-06 - mae: 7.6514e-04 - val_loss: 1.4572e-05 - val_mae: 0.0020

Epoch 251/600
17/17 0s 6ms/step - loss:
2.4330e-06 - mae: 7.4780e-04 - val_loss: 1.4507e-05 - val_mae: 0.0020

Epoch 252/600
17/17 0s 8ms/step - loss:
2.3216e-06 - mae: 7.3157e-04 - val_loss: 1.4434e-05 - val_mae: 0.0020

Epoch 253/600
17/17 0s 8ms/step - loss:
2.2201e-06 - mae: 7.1631e-04 - val_loss: 1.4352e-05 - val_mae: 0.0020

Epoch 254/600
17/17 0s 9ms/step - loss:
2.1272e-06 - mae: 7.0196e-04 - val_loss: 1.4262e-05 - val_mae: 0.0020

Epoch 255/600
17/17 0s 7ms/step - loss:
2.0418e-06 - mae: 6.8841e-04 - val_loss: 1.4166e-05 - val_mae: 0.0019

Epoch 256/600
17/17 0s 5ms/step - loss:
1.9632e-06 - mae: 6.7562e-04 - val_loss: 1.4064e-05 - val_mae: 0.0019

Epoch 257/600
17/17 0s 5ms/step - loss:
1.8904e-06 - mae: 6.6351e-04 - val_loss: 1.3959e-05 - val_mae: 0.0019

Epoch 258/600
17/17 0s 5ms/step - loss:
1.8229e-06 - mae: 6.5204e-04 - val_loss: 1.3850e-05 - val_mae: 0.0019

Epoch 259/600
17/17 0s 4ms/step - loss:
1.7601e-06 - mae: 6.4113e-04 - val_loss: 1.3737e-05 - val_mae: 0.0019

Epoch 260/600
17/17 0s 5ms/step - loss:
1.7017e-06 - mae: 6.3078e-04 - val_loss: 1.4821e-05 - val_mae: 0.0020

Epoch 261/600
17/17 0s 5ms/step - loss:
1.5651e-06 - mae: 6.0863e-04 - val_loss: 1.3618e-05 - val_mae: 0.0019

Epoch 262/600
17/17 0s 4ms/step - loss:
1.6006e-06 - mae: 6.1231e-04 - val_loss: 1.3628e-05 - val_mae: 0.0019

Epoch 263/600
17/17 0s 7ms/step - loss:
1.5353e-06 - mae: 6.0056e-04 - val_loss: 1.3312e-05 - val_mae: 0.0019

Epoch 264/600
17/17 0s 4ms/step - loss:
1.5168e-06 - mae: 5.9640e-04 - val_loss: 1.3411e-05 - val_mae: 0.0019

Epoch 265/600
17/17 0s 4ms/step - loss:
1.4594e-06 - mae: 5.8609e-04 - val_loss: 1.3325e-05 - val_mae: 0.0019

Epoch 266/600
17/17 0s 5ms/step - loss:
1.4181e-06 - mae: 5.7815e-04 - val_loss: 1.3222e-05 - val_mae: 0.0019

Epoch 267/600
17/17 0s 4ms/step - loss:
1.3802e-06 - mae: 5.7071e-04 - val_loss: 1.3116e-05 - val_mae: 0.0019

Epoch 268/600
17/17 0s 5ms/step - loss:
1.3443e-06 - mae: 5.6358e-04 - val_loss: 1.3010e-05 - val_mae: 0.0019

Epoch 269/600
17/17 0s 5ms/step - loss:
1.3032e-06 - mae: 5.5520e-04 - val_loss: 1.3556e-05 - val_mae: 0.0019

Epoch 270/600
17/17 0s 4ms/step - loss:
1.2399e-06 - mae: 5.4331e-04 - val_loss: 1.2898e-05 - val_mae: 0.0018

Epoch 271/600
17/17 0s 4ms/step - loss:
1.2436e-06 - mae: 5.4275e-04 - val_loss: 1.2716e-05 - val_mae: 0.0018

Epoch 272/600
17/17 0s 4ms/step - loss:
1.2192e-06 - mae: 5.3741e-04 - val_loss: 1.2601e-05 - val_mae: 0.0018

Epoch 273/600
17/17 0s 4ms/step - loss:
1.1919e-06 - mae: 5.3158e-04 - val_loss: 1.2496e-05 - val_mae: 0.0018

Epoch 274/600
17/17 0s 5ms/step - loss:
1.1653e-06 - mae: 5.2584e-04 - val_loss: 1.2393e-05 - val_mae: 0.0018

Epoch 275/600
17/17 0s 4ms/step - loss:
1.1340e-06 - mae: 5.1896e-04 - val_loss: 1.2808e-05 - val_mae: 0.0018

Epoch 276/600
17/17 0s 4ms/step - loss:
1.0872e-06 - mae: 5.0949e-04 - val_loss: 1.2295e-05 - val_mae: 0.0018

Epoch 277/600
17/17 0s 4ms/step - loss:
1.0877e-06 - mae: 5.0858e-04 - val_loss: 1.2119e-05 - val_mae: 0.0018

Epoch 278/600
17/17 0s 5ms/step - loss:
1.0697e-06 - mae: 5.0432e-04 - val_loss: 1.2006e-05 - val_mae: 0.0018

Epoch 279/600
17/17 0s 7ms/step - loss:
1.0490e-06 - mae: 4.9956e-04 - val_loss: 1.1905e-05 - val_mae: 0.0018

Epoch 280/600
17/17 0s 4ms/step - loss:
1.0233e-06 - mae: 4.9358e-04 - val_loss: 1.2246e-05 - val_mae: 0.0018

Epoch 281/600
17/17 0s 4ms/step - loss:
9.8595e-07 - mae: 4.8559e-04 - val_loss: 1.1817e-05 - val_mae: 0.0018

Epoch 282/600
17/17 0s 5ms/step - loss:
9.8511e-07 - mae: 4.8456e-04 - val_loss: 1.1650e-05 - val_mae: 0.0017

Epoch 283/600
17/17 0s 4ms/step - loss:
9.7077e-07 - mae: 4.8096e-04 - val_loss: 1.1540e-05 - val_mae: 0.0017

Epoch 284/600
17/17 0s 5ms/step - loss:
9.5391e-07 - mae: 4.7686e-04 - val_loss: 1.1444e-05 - val_mae: 0.0017

Epoch 285/600
17/17 0s 4ms/step - loss:
9.3693e-07 - mae: 4.7274e-04 - val_loss: 1.1353e-05 - val_mae: 0.0017

Epoch 286/600
17/17 0s 5ms/step - loss:
9.1643e-07 - mae: 4.6767e-04 - val_loss: 1.1623e-05 - val_mae: 0.0017

Epoch 287/600
17/17 0s 5ms/step - loss:
8.7656e-07 - mae: 4.5832e-04 - val_loss: 1.1263e-05 - val_mae: 0.0017

Epoch 288/600
17/17 0s 5ms/step - loss:
8.8766e-07 - mae: 4.5988e-04 - val_loss: 1.1126e-05 - val_mae: 0.0017

Epoch 289/600
17/17 0s 4ms/step - loss:
8.7533e-07 - mae: 4.5666e-04 - val_loss: 1.1026e-05 - val_mae: 0.0017

Epoch 290/600
17/17 0s 4ms/step - loss:
8.6152e-07 - mae: 4.5311e-04 - val_loss: 1.0938e-05 - val_mae: 0.0017

Epoch 291/600
17/17 0s 5ms/step - loss:
8.4768e-07 - mae: 4.4957e-04 - val_loss: 1.0853e-05 - val_mae: 0.0017

Epoch 292/600
17/17 0s 5ms/step - loss:
8.3414e-07 - mae: 4.4608e-04 - val_loss: 1.0770e-05 - val_mae: 0.0017

Epoch 293/600
17/17 0s 5ms/step - loss:
8.2099e-07 - mae: 4.4267e-04 - val_loss: 1.0688e-05 - val_mae: 0.0017

Epoch 294/600
17/17 0s 4ms/step - loss:
8.0457e-07 - mae: 4.3836e-04 - val_loss: 1.0398e-05 - val_mae: 0.0016

Epoch 295/600
17/17 0s 4ms/step - loss:
8.0722e-07 - mae: 4.3837e-04 - val_loss: 1.0464e-05 - val_mae: 0.0017

Epoch 296/600
17/17 0s 5ms/step - loss:
7.8268e-07 - mae: 4.3221e-04 - val_loss: 1.0575e-05 - val_mae: 0.0017

Epoch 297/600
17/17 0s 7ms/step - loss:
7.6436e-07 - mae: 4.2743e-04 - val_loss: 1.0220e-05 - val_mae: 0.0016

Epoch 298/600
17/17 0s 5ms/step - loss:
7.7073e-07 - mae: 4.2829e-04 - val_loss: 1.0255e-05 - val_mae: 0.0016

Epoch 299/600
17/17 0s 5ms/step - loss:
7.5398e-07 - mae: 4.2406e-04 - val_loss: 1.0216e-05 - val_mae: 0.0016

Epoch 300/600
17/17 0s 5ms/step - loss:
7.3673e-07 - mae: 4.1940e-04 - val_loss: 9.8484e-06 - val_mae: 0.0016

Epoch 301/600
17/17 0s 5ms/step - loss:
7.4653e-07 - mae: 4.2105e-04 - val_loss: 9.9811e-06 - val_mae: 0.0016

Epoch 302/600
17/17 0s 5ms/step - loss:
7.2579e-07 - mae: 4.1592e-04 - val_loss: 9.9805e-06 - val_mae: 0.0016

Epoch 303/600
17/17 0s 4ms/step - loss:
7.0968e-07 - mae: 4.1161e-04 - val_loss: 9.7433e-06 - val_mae: 0.0016

Epoch 304/600
17/17 0s 5ms/step - loss:
7.1134e-07 - mae: 4.1151e-04 - val_loss: 9.8048e-06 - val_mae: 0.0016

Epoch 305/600
17/17 0s 4ms/step - loss:
6.9132e-07 - mae: 4.0619e-04 - val_loss: 9.8816e-06 - val_mae: 0.0016

Epoch 306/600
17/17 0s 5ms/step - loss:
6.7790e-07 - mae: 4.0243e-04 - val_loss: 9.5902e-06 - val_mae: 0.0016

Epoch 307/600
17/17 0s 4ms/step - loss:
6.8243e-07 - mae: 4.0302e-04 - val_loss: 9.6233e-06 - val_mae: 0.0016

Epoch 308/600
17/17 0s 5ms/step - loss:
6.6886e-07 - mae: 3.9940e-04 - val_loss: 9.5946e-06 - val_mae: 0.0016

Epoch 309/600
17/17 0s 5ms/step - loss:
6.5466e-07 - mae: 3.9535e-04 - val_loss: 9.2646e-06 - val_mae: 0.0016

Epoch 310/600
17/17 0s 4ms/step - loss:
6.6359e-07 - mae: 3.9700e-04 - val_loss: 9.3764e-06 - val_mae: 0.0016

Epoch 311/600
17/17 0s 4ms/step - loss:
6.5287e-07 - mae: 3.9384e-04 - val_loss: 9.2335e-06 - val_mae: 0.0016

Epoch 312/600
17/17 0s 4ms/step - loss:
6.4297e-07 - mae: 3.9116e-04 - val_loss: 9.2866e-06 - val_mae: 0.0016

Epoch 313/600
17/17 0s 5ms/step - loss:
6.2789e-07 - mae: 3.8698e-04 - val_loss: 9.1069e-06 - val_mae: 0.0015

Epoch 314/600
17/17 0s 5ms/step - loss:
6.2807e-07 - mae: 3.8662e-04 - val_loss: 9.1619e-06 - val_mae: 0.0015

Epoch 315/600
17/17 0s 5ms/step - loss:
6.2127e-07 - mae: 3.8436e-04 - val_loss: 9.3521e-06 - val_mae: 0.0016

Epoch 316/600
17/17 0s 5ms/step - loss:
6.0016e-07 - mae: 3.7845e-04 - val_loss: 8.8013e-06 - val_mae: 0.0015

Epoch 317/600
17/17 0s 4ms/step - loss:
6.1348e-07 - mae: 3.8140e-04 - val_loss: 8.9319e-06 - val_mae: 0.0015

Epoch 318/600
17/17 0s 5ms/step - loss:
5.9590e-07 - mae: 3.7658e-04 - val_loss: 8.7973e-06 - val_mae: 0.0015

Epoch 319/600
17/17 0s 5ms/step - loss:
5.9465e-07 - mae: 3.7591e-04 - val_loss: 8.8637e-06 - val_mae: 0.0015

Epoch 320/600
17/17 0s 5ms/step - loss:
5.8775e-07 - mae: 3.7362e-04 - val_loss: 8.7273e-06 - val_mae: 0.0015

Epoch 321/600
17/17 0s 7ms/step - loss:
5.7727e-07 - mae: 3.7052e-04 - val_loss: 8.8195e-06 - val_mae: 0.0015

Epoch 322/600
17/17 0s 5ms/step - loss:
5.7251e-07 - mae: 3.6875e-04 - val_loss: 8.6526e-06 - val_mae: 0.0015

Epoch 323/600
17/17 0s 4ms/step - loss:
5.6212e-07 - mae: 3.6551e-04 - val_loss: 8.5676e-06 - val_mae: 0.0015

Epoch 324/600
17/17 0s 5ms/step - loss:
5.6720e-07 - mae: 3.6627e-04 - val_loss: 8.4837e-06 - val_mae: 0.0015

Epoch 325/600
17/17 0s 5ms/step - loss:
5.5808e-07 - mae: 3.6372e-04 - val_loss: 8.5463e-06 - val_mae: 0.0015

Epoch 326/600
17/17 0s 5ms/step - loss:
5.5141e-07 - mae: 3.6149e-04 - val_loss: 8.4195e-06 - val_mae: 0.0015

Epoch 327/600
17/17 0s 4ms/step - loss:
5.4074e-07 - mae: 3.5816e-04 - val_loss: 8.0854e-06 - val_mae: 0.0014

Epoch 328/600
17/17 0s 5ms/step - loss:
5.5285e-07 - mae: 3.6098e-04 - val_loss: 8.2771e-06 - val_mae: 0.0015

Epoch 329/600
17/17 0s 4ms/step - loss:
5.3598e-07 - mae: 3.5634e-04 - val_loss: 8.3400e-06 - val_mae: 0.0015

Epoch 330/600
17/17 0s 4ms/step - loss:
5.3014e-07 - mae: 3.5431e-04 - val_loss: 8.2232e-06 - val_mae: 0.0015

Epoch 331/600
17/17 0s 5ms/step - loss:
5.1961e-07 - mae: 3.5102e-04 - val_loss: 7.9024e-06 - val_mae: 0.0014

Epoch 332/600
17/17 0s 5ms/step - loss:
5.3110e-07 - mae: 3.5375e-04 - val_loss: 8.0827e-06 - val_mae: 0.0014

Epoch 333/600
17/17 0s 5ms/step - loss:
5.1980e-07 - mae: 3.5033e-04 - val_loss: 8.0270e-06 - val_mae: 0.0014

Epoch 334/600
17/17 0s 5ms/step - loss:
5.0943e-07 - mae: 3.4727e-04 - val_loss: 7.9584e-06 - val_mae: 0.0014

Epoch 335/600
17/17 0s 8ms/step - loss:
5.1118e-07 - mae: 3.4728e-04 - val_loss: 7.9192e-06 - val_mae: 0.0014

Epoch 336/600
17/17 0s 9ms/step - loss:
4.9988e-07 - mae: 3.4390e-04 - val_loss: 7.7789e-06 - val_mae: 0.0014

Epoch 337/600
17/17 0s 8ms/step - loss:
5.0186e-07 - mae: 3.4413e-04 - val_loss: 7.8994e-06 - val_mae: 0.0014

Epoch 338/600
17/17 0s 9ms/step - loss:
4.9390e-07 - mae: 3.4156e-04 - val_loss: 7.8255e-06 - val_mae: 0.0014

Epoch 339/600
17/17 0s 8ms/step - loss:
4.9010e-07 - mae: 3.4016e-04 - val_loss: 7.7648e-06 - val_mae: 0.0014

Epoch 340/600
17/17 0s 4ms/step - loss:
4.8051e-07 - mae: 3.3707e-04 - val_loss: 7.7131e-06 - val_mae: 0.0014

Epoch 341/600
17/17 0s 7ms/step - loss:
4.7951e-07 - mae: 3.3655e-04 - val_loss: 7.7785e-06 - val_mae: 0.0014

Epoch 342/600
17/17 0s 6ms/step - loss:
4.7423e-07 - mae: 3.3467e-04 - val_loss: 7.6840e-06 - val_mae: 0.0014

Epoch 343/600
17/17 0s 5ms/step - loss:
4.6596e-07 - mae: 3.3192e-04 - val_loss: 7.4042e-06 - val_mae: 0.0014

Epoch 344/600
17/17 0s 5ms/step - loss:
4.7518e-07 - mae: 3.3424e-04 - val_loss: 7.5558e-06 - val_mae: 0.0014

Epoch 345/600
17/17 0s 4ms/step - loss:
4.6603e-07 - mae: 3.3132e-04 - val_loss: 7.5100e-06 - val_mae: 0.0014

Epoch 346/600
17/17 0s 4ms/step - loss:
4.5565e-07 - mae: 3.2798e-04 - val_loss: 7.2602e-06 - val_mae: 0.0014

Epoch 347/600
17/17 0s 5ms/step - loss:
4.6431e-07 - mae: 3.3018e-04 - val_loss: 7.4196e-06 - val_mae: 0.0014

Epoch 348/600
17/17 0s 5ms/step - loss:
4.5511e-07 - mae: 3.2722e-04 - val_loss: 7.3836e-06 - val_mae: 0.0014

Epoch 349/600
17/17 0s 5ms/step - loss:
4.5073e-07 - mae: 3.2568e-04 - val_loss: 7.3453e-06 - val_mae: 0.0014

Epoch 350/600
17/17 0s 5ms/step - loss:
4.4126e-07 - mae: 3.2258e-04 - val_loss: 7.3008e-06 - val_mae: 0.0014

Epoch 351/600
17/17 0s 5ms/step - loss:
4.4393e-07 - mae: 3.2298e-04 - val_loss: 7.2679e-06 - val_mae: 0.0014

Epoch 352/600
17/17 0s 5ms/step - loss:
4.3588e-07 - mae: 3.2044e-04 - val_loss: 7.2187e-06 - val_mae: 0.0014

Epoch 353/600
17/17 0s 4ms/step - loss:
4.3691e-07 - mae: 3.2037e-04 - val_loss: 7.1893e-06 - val_mae: 0.0014

Epoch 354/600
17/17 0s 4ms/step - loss:
4.2852e-07 - mae: 3.1766e-04 - val_loss: 7.0748e-06 - val_mae: 0.0014

Epoch 355/600
17/17 0s 4ms/step - loss:
4.3013e-07 - mae: 3.1790e-04 - val_loss: 7.1739e-06 - val_mae: 0.0014

Epoch 356/600
17/17 0s 5ms/step - loss:
4.2392e-07 - mae: 3.1575e-04 - val_loss: 7.1177e-06 - val_mae: 0.0014

Epoch 357/600
17/17 0s 4ms/step - loss:
4.1617e-07 - mae: 3.1309e-04 - val_loss: 6.8856e-06 - val_mae: 0.0013

Epoch 358/600
17/17 0s 4ms/step - loss:
4.2373e-07 - mae: 3.1511e-04 - val_loss: 7.0186e-06 - val_mae: 0.0013

Epoch 359/600
17/17 0s 4ms/step - loss:
4.1610e-07 - mae: 3.1254e-04 - val_loss: 6.9851e-06 - val_mae: 0.0013

Epoch 360/600
17/17 0s 4ms/step - loss:
4.1249e-07 - mae: 3.1122e-04 - val_loss: 6.9505e-06 - val_mae: 0.0013

Epoch 361/600
17/17 0s 5ms/step - loss:
4.0476e-07 - mae: 3.0856e-04 - val_loss: 6.7387e-06 - val_mae: 0.0013

Epoch 362/600
17/17 0s 7ms/step - loss:
4.1145e-07 - mae: 3.1035e-04 - val_loss: 6.8720e-06 - val_mae: 0.0013

Epoch 363/600
17/17 0s 7ms/step - loss:
4.0379e-07 - mae: 3.0777e-04 - val_loss: 6.8437e-06 - val_mae: 0.0013

Epoch 364/600
17/17 0s 5ms/step - loss:
3.9580e-07 - mae: 3.0502e-04 - val_loss: 6.6400e-06 - val_mae: 0.0013

Epoch 365/600
17/17 0s 7ms/step - loss:
4.0243e-07 - mae: 3.0682e-04 - val_loss: 6.7704e-06 - val_mae: 0.0013

Epoch 366/600
17/17 0s 5ms/step - loss:
3.9515e-07 - mae: 3.0434e-04 - val_loss: 6.7449e-06 - val_mae: 0.0013

Epoch 367/600
17/17 0s 5ms/step - loss:
3.9166e-07 - mae: 3.0305e-04 - val_loss: 6.7159e-06 - val_mae: 0.0013

Epoch 368/600
17/17 0s 7ms/step - loss:
3.8459e-07 - mae: 3.0054e-04 - val_loss: 6.6749e-06 - val_mae: 0.0013

Epoch 369/600
17/17 0s 4ms/step - loss:
3.8655e-07 - mae: 3.0085e-04 - val_loss: 6.6505e-06 - val_mae: 0.0013

Epoch 370/600
17/17 0s 5ms/step - loss:
3.8040e-07 - mae: 2.9877e-04 - val_loss: 6.6121e-06 - val_mae: 0.0013

Epoch 371/600
17/17 0s 5ms/step - loss:
3.8098e-07 - mae: 2.9866e-04 - val_loss: 6.5882e-06 - val_mae: 0.0013

Epoch 372/600
17/17 0s 5ms/step - loss:
3.7472e-07 - mae: 2.9648e-04 - val_loss: 6.4929e-06 - val_mae: 0.0013

Epoch 373/600
17/17 0s 5ms/step - loss:
3.7592e-07 - mae: 2.9668e-04 - val_loss: 6.5753e-06 - val_mae: 0.0013

Epoch 374/600
17/17 0s 5ms/step - loss:
3.7092e-07 - mae: 2.9483e-04 - val_loss: 6.5308e-06 - val_mae: 0.0013

Epoch 375/600
17/17 0s 5ms/step - loss:
3.6514e-07 - mae: 2.9271e-04 - val_loss: 6.3362e-06 - val_mae: 0.0013

Epoch 376/600
17/17 0s 5ms/step - loss:
3.7102e-07 - mae: 2.9439e-04 - val_loss: 6.4438e-06 - val_mae: 0.0013

Epoch 377/600
17/17 0s 7ms/step - loss:
3.6502e-07 - mae: 2.9224e-04 - val_loss: 6.4174e-06 - val_mae: 0.0013

Epoch 378/600
17/17 0s 5ms/step - loss:
3.5845e-07 - mae: 2.8987e-04 - val_loss: 6.2367e-06 - val_mae: 0.0013

Epoch 379/600
17/17 0s 5ms/step - loss:
3.6416e-07 - mae: 2.9151e-04 - val_loss: 6.3474e-06 - val_mae: 0.0013

Epoch 380/600
17/17 0s 5ms/step - loss:
3.5819e-07 - mae: 2.8936e-04 - val_loss: 6.3261e-06 - val_mae: 0.0013

Epoch 381/600
17/17 0s 5ms/step - loss:
3.5527e-07 - mae: 2.8822e-04 - val_loss: 6.3017e-06 - val_mae: 0.0013

Epoch 382/600
17/17 0s 5ms/step - loss:
3.4931e-07 - mae: 2.8603e-04 - val_loss: 6.1288e-06 - val_mae: 0.0013

Epoch 383/600
17/17 0s 5ms/step - loss:
3.5453e-07 - mae: 2.8755e-04 - val_loss: 6.2351e-06 - val_mae: 0.0013

Epoch 384/600
17/17 0s 4ms/step - loss:
3.4874e-07 - mae: 2.8545e-04 - val_loss: 6.2149e-06 - val_mae: 0.0013

Epoch 385/600
17/17 0s 4ms/step - loss:
3.4259e-07 - mae: 2.8318e-04 - val_loss: 6.1783e-06 - val_mae: 0.0013

Epoch 386/600
17/17 0s 5ms/step - loss:
3.4455e-07 - mae: 2.8355e-04 - val_loss: 6.1607e-06 - val_mae: 0.0013

Epoch 387/600
17/17 0s 5ms/step - loss:
3.4004e-07 - mae: 2.8200e-04 - val_loss: 6.2123e-06 - val_mae: 0.0013

Epoch 388/600
17/17 0s 5ms/step - loss:
3.3605e-07 - mae: 2.8038e-04 - val_loss: 6.0804e-06 - val_mae: 0.0013

Epoch 389/600
17/17 0s 5ms/step - loss:
3.3569e-07 - mae: 2.8006e-04 - val_loss: 6.0095e-06 - val_mae: 0.0012

Epoch 390/600
17/17 0s 5ms/step - loss:
3.3653e-07 - mae: 2.8018e-04 - val_loss: 6.0872e-06 - val_mae: 0.0013

Epoch 391/600
17/17 0s 5ms/step - loss:
3.3222e-07 - mae: 2.7853e-04 - val_loss: 6.0560e-06 - val_mae: 0.0012

Epoch 392/600
17/17 0s 4ms/step - loss:
3.3010e-07 - mae: 2.7764e-04 - val_loss: 6.0264e-06 - val_mae: 0.0012

Epoch 393/600
17/17 0s 5ms/step - loss:
3.2542e-07 - mae: 2.7582e-04 - val_loss: 5.8647e-06 - val_mae: 0.0012

Epoch 394/600
17/17 0s 4ms/step - loss:
3.3004e-07 - mae: 2.7721e-04 - val_loss: 5.9562e-06 - val_mae: 0.0012

Epoch 395/600
17/17 0s 4ms/step - loss:
3.2504e-07 - mae: 2.7533e-04 - val_loss: 5.9363e-06 - val_mae: 0.0012

Epoch 396/600
17/17 0s 4ms/step - loss:
3.1989e-07 - mae: 2.7336e-04 - val_loss: 5.7835e-06 - val_mae: 0.0012

Epoch 397/600
17/17 0s 5ms/step - loss:
3.2443e-07 - mae: 2.7474e-04 - val_loss: 5.8761e-06 - val_mae: 0.0012

Epoch 398/600
17/17 0s 5ms/step - loss:
3.1953e-07 - mae: 2.7288e-04 - val_loss: 5.8597e-06 - val_mae: 0.0012

Epoch 399/600
17/17 0s 5ms/step - loss:
3.1422e-07 - mae: 2.7085e-04 - val_loss: 5.7118e-06 - val_mae: 0.0012

Epoch 400/600
17/17 0s 5ms/step - loss:
3.1874e-07 - mae: 2.7224e-04 - val_loss: 5.8028e-06 - val_mae: 0.0012

Epoch 401/600
17/17 0s 7ms/step - loss:
3.1405e-07 - mae: 2.7045e-04 - val_loss: 5.7881e-06 - val_mae: 0.0012

Epoch 402/600
17/17 0s 4ms/step - loss:
3.1169e-07 - mae: 2.6947e-04 - val_loss: 5.7699e-06 - val_mae: 0.0012

Epoch 403/600
17/17 0s 4ms/step - loss:
3.0697e-07 - mae: 2.6762e-04 - val_loss: 5.7362e-06 - val_mae: 0.0012

Epoch 404/600
17/17 0s 5ms/step - loss:
3.0844e-07 - mae: 2.6791e-04 - val_loss: 5.7211e-06 - val_mae: 0.0012

Epoch 405/600
17/17 0s 5ms/step - loss:
3.0331e-07 - mae: 2.6593e-04 - val_loss: 5.5801e-06 - val_mae: 0.0012

Epoch 406/600
17/17 0s 5ms/step - loss:
3.0778e-07 - mae: 2.6733e-04 - val_loss: 5.6666e-06 - val_mae: 0.0012

Epoch 407/600
17/17 0s 4ms/step - loss:
3.0333e-07 - mae: 2.6560e-04 - val_loss: 5.6531e-06 - val_mae: 0.0012

Epoch 408/600
17/17 0s 5ms/step - loss:
3.0110e-07 - mae: 2.6467e-04 - val_loss: 5.6361e-06 - val_mae: 0.0012

Epoch 409/600
17/17 0s 5ms/step - loss:
2.9652e-07 - mae: 2.6287e-04 - val_loss: 5.4987e-06 - val_mae: 0.0012

Epoch 410/600
17/17 0s 5ms/step - loss:
3.0065e-07 - mae: 2.6417e-04 - val_loss: 5.5809e-06 - val_mae: 0.0012

Epoch 411/600
17/17 0s 5ms/step - loss:
2.9636e-07 - mae: 2.6248e-04 - val_loss: 5.5671e-06 - val_mae: 0.0012

Epoch 412/600
17/17 0s 7ms/step - loss:
2.9164e-07 - mae: 2.6062e-04 - val_loss: 5.4338e-06 - val_mae: 0.0012

Epoch 413/600
17/17 0s 5ms/step - loss:
2.9577e-07 - mae: 2.6194e-04 - val_loss: 5.5150e-06 - val_mae: 0.0012

Epoch 414/600
17/17 0s 5ms/step - loss:
2.9164e-07 - mae: 2.6030e-04 - val_loss: 5.5025e-06 - val_mae: 0.0012

Epoch 415/600
17/17 0s 5ms/step - loss:
2.8955e-07 - mae: 2.5941e-04 - val_loss: 5.4869e-06 - val_mae: 0.0012

Epoch 416/600
17/17 0s 7ms/step - loss:
2.8533e-07 - mae: 2.5771e-04 - val_loss: 5.3569e-06 - val_mae: 0.0012

Epoch 417/600
17/17 0s 7ms/step - loss:
2.8916e-07 - mae: 2.5895e-04 - val_loss: 5.4341e-06 - val_mae: 0.0012

Epoch 418/600
17/17 0s 8ms/step - loss:
2.8518e-07 - mae: 2.5736e-04 - val_loss: 5.4214e-06 - val_mae: 0.0012

Epoch 419/600
17/17 0s 9ms/step - loss:
2.8080e-07 - mae: 2.5559e-04 - val_loss: 5.2955e-06 - val_mae: 0.0012

Epoch 420/600
17/17 0s 8ms/step - loss:
2.8462e-07 - mae: 2.5684e-04 - val_loss: 5.3717e-06 - val_mae: 0.0012

Epoch 421/600
17/17 0s 7ms/step - loss:
2.8079e-07 - mae: 2.5529e-04 - val_loss: 5.3603e-06 - val_mae: 0.0012

Epoch 422/600
17/17 0s 8ms/step - loss:
2.7883e-07 - mae: 2.5445e-04 - val_loss: 5.3459e-06 - val_mae: 0.0012

Epoch 423/600
17/17 0s 9ms/step - loss:
2.7495e-07 - mae: 2.5284e-04 - val_loss: 5.3158e-06 - val_mae: 0.0012

Epoch 424/600
17/17 0s 6ms/step - loss:
2.7623e-07 - mae: 2.5312e-04 - val_loss: 5.3039e-06 - val_mae: 0.0012

Epoch 425/600
17/17 0s 4ms/step - loss:
2.7254e-07 - mae: 2.5165e-04 - val_loss: 5.2443e-06 - val_mae: 0.0012

Epoch 426/600
17/17 0s 5ms/step - loss:
2.7344e-07 - mae: 2.5186e-04 - val_loss: 5.2975e-06 - val_mae: 0.0012

Epoch 427/600
17/17 0s 4ms/step - loss:
2.7058e-07 - mae: 2.5064e-04 - val_loss: 5.2739e-06 - val_mae: 0.0012

Epoch 428/600
17/17 0s 5ms/step - loss:
2.6714e-07 - mae: 2.4918e-04 - val_loss: 5.1484e-06 - val_mae: 0.0011

Epoch 429/600
17/17 0s 5ms/step - loss:
2.7075e-07 - mae: 2.5039e-04 - val_loss: 5.2130e-06 - val_mae: 0.0012

Epoch 430/600
17/17 0s 7ms/step - loss:
2.6747e-07 - mae: 2.4904e-04 - val_loss: 5.1985e-06 - val_mae: 0.0012

Epoch 431/600
17/17 0s 5ms/step - loss:
2.6582e-07 - mae: 2.4829e-04 - val_loss: 5.1825e-06 - val_mae: 0.0012

Epoch 432/600
17/17 0s 5ms/step - loss:
2.6239e-07 - mae: 2.4684e-04 - val_loss: 5.0657e-06 - val_mae: 0.0011

Epoch 433/600
17/17 0s 5ms/step - loss:
2.6571e-07 - mae: 2.4795e-04 - val_loss: 5.1317e-06 - val_mae: 0.0011

Epoch 434/600
17/17 0s 7ms/step - loss:
2.6232e-07 - mae: 2.4653e-04 - val_loss: 5.1200e-06 - val_mae: 0.0011

Epoch 435/600
17/17 0s 5ms/step - loss:
2.5868e-07 - mae: 2.4501e-04 - val_loss: 5.0079e-06 - val_mae: 0.0011

Epoch 436/600
17/17 0s 5ms/step - loss:
2.6196e-07 - mae: 2.4612e-04 - val_loss: 5.0741e-06 - val_mae: 0.0011

Epoch 437/600
17/17 0s 4ms/step - loss:
2.5866e-07 - mae: 2.4475e-04 - val_loss: 5.0641e-06 - val_mae: 0.0011

Epoch 438/600
17/17 0s 4ms/step - loss:
2.5566e-07 - mae: 2.4351e-04 - val_loss: 5.0460e-06 - val_mae: 0.0011

Epoch 439/600
17/17 0s 4ms/step - loss:
2.5587e-07 - mae: 2.4344e-04 - val_loss: 5.0341e-06 - val_mae: 0.0011

Epoch 440/600
17/17 0s 5ms/step - loss:
2.5238e-07 - mae: 2.4195e-04 - val_loss: 4.9255e-06 - val_mae: 0.0011

Epoch 441/600
17/17 0s 5ms/step - loss:
2.5553e-07 - mae: 2.4303e-04 - val_loss: 4.9885e-06 - val_mae: 0.0011

Epoch 442/600
17/17 0s 5ms/step - loss:
2.5245e-07 - mae: 2.4172e-04 - val_loss: 4.9791e-06 - val_mae: 0.0011

Epoch 443/600
17/17 0s 5ms/step - loss:
2.5085e-07 - mae: 2.4100e-04 - val_loss: 4.9671e-06 - val_mae: 0.0011

Epoch 444/600
17/17 0s 7ms/step - loss:
2.4767e-07 - mae: 2.3961e-04 - val_loss: 4.9403e-06 - val_mae: 0.0011

Epoch 445/600
17/17 0s 5ms/step - loss:
2.4876e-07 - mae: 2.3987e-04 - val_loss: 4.9304e-06 - val_mae: 0.0011

Epoch 446/600
17/17 0s 4ms/step - loss:
2.4575e-07 - mae: 2.3860e-04 - val_loss: 4.8796e-06 - val_mae: 0.0011

Epoch 447/600
17/17 0s 4ms/step - loss:
2.4646e-07 - mae: 2.3877e-04 - val_loss: 4.9252e-06 - val_mae: 0.0011

Epoch 448/600
17/17 0s 5ms/step - loss:
2.4411e-07 - mae: 2.3773e-04 - val_loss: 4.9060e-06 - val_mae: 0.0011

Epoch 449/600
17/17 0s 4ms/step - loss:
2.4258e-07 - mae: 2.3697e-04 - val_loss: 4.8352e-06 - val_mae: 0.0011

Epoch 450/600
17/17 0s 5ms/step - loss:
2.4288e-07 - mae: 2.3703e-04 - val_loss: 4.8787e-06 - val_mae: 0.0011

Epoch 451/600
17/17 0s 6ms/step - loss:
2.3988e-07 - mae: 2.3566e-04 - val_loss: 4.7749e-06 - val_mae: 0.0011

Epoch 452/600
17/17 0s 5ms/step - loss:
2.4169e-07 - mae: 2.3630e-04 - val_loss: 4.8262e-06 - val_mae: 0.0011

Epoch 453/600
17/17 0s 4ms/step - loss:
2.3742e-07 - mae: 2.3446e-04 - val_loss: 4.7257e-06 - val_mae: 0.0011

Epoch 454/600
17/17 0s 4ms/step - loss:
2.4016e-07 - mae: 2.3543e-04 - val_loss: 4.7816e-06 - val_mae: 0.0011

Epoch 455/600
17/17 0s 5ms/step - loss:
2.3737e-07 - mae: 2.3420e-04 - val_loss: 4.7721e-06 - val_mae: 0.0011

Epoch 456/600
17/17 0s 5ms/step - loss:
2.3435e-07 - mae: 2.3286e-04 - val_loss: 4.6755e-06 - val_mae: 0.0011

Epoch 457/600
17/17 0s 5ms/step - loss:
2.3710e-07 - mae: 2.3386e-04 - val_loss: 4.7317e-06 - val_mae: 0.0011

Epoch 458/600
17/17 0s 5ms/step - loss:
2.3437e-07 - mae: 2.3265e-04 - val_loss: 4.7237e-06 - val_mae: 0.0011

Epoch 459/600
17/17 0s 5ms/step - loss:
2.3184e-07 - mae: 2.3158e-04 - val_loss: 4.7086e-06 - val_mae: 0.0011

Epoch 460/600
17/17 0s 5ms/step - loss:
2.3202e-07 - mae: 2.3150e-04 - val_loss: 4.6987e-06 - val_mae: 0.0011

Epoch 461/600
17/17 0s 5ms/step - loss:
2.2913e-07 - mae: 2.3021e-04 - val_loss: 4.6744e-06 - val_mae: 0.0011

Epoch 462/600
17/17 0s 4ms/step - loss:
2.3022e-07 - mae: 2.3051e-04 - val_loss: 4.6664e-06 - val_mae: 0.0011

Epoch 463/600
17/17 0s 7ms/step - loss:
2.2752e-07 - mae: 2.2933e-04 - val_loss: 4.6214e-06 - val_mae: 0.0011

Epoch 464/600
17/17 0s 9ms/step - loss:
2.2817e-07 - mae: 2.2949e-04 - val_loss: 4.6622e-06 - val_mae: 0.0011

Epoch 465/600
17/17 0s 8ms/step - loss:
2.2616e-07 - mae: 2.2856e-04 - val_loss: 4.6459e-06 - val_mae: 0.0011

Epoch 466/600
17/17 0s 8ms/step - loss:
2.2477e-07 - mae: 2.2786e-04 - val_loss: 4.5829e-06 - val_mae: 0.0011

Epoch 467/600
17/17 0s 8ms/step - loss:
2.2503e-07 - mae: 2.2792e-04 - val_loss: 4.6217e-06 - val_mae: 0.0011

Epoch 468/600
17/17 0s 8ms/step - loss:
2.2248e-07 - mae: 2.2669e-04 - val_loss: 4.5293e-06 - val_mae: 0.0011

Epoch 469/600
17/17 0s 8ms/step - loss:
2.2401e-07 - mae: 2.2726e-04 - val_loss: 4.5745e-06 - val_mae: 0.0011

Epoch 470/600
17/17 0s 5ms/step - loss:
2.2025e-07 - mae: 2.2557e-04 - val_loss: 4.4845e-06 - val_mae: 0.0011

Epoch 471/600
17/17 0s 4ms/step - loss:
2.2273e-07 - mae: 2.2649e-04 - val_loss: 4.5338e-06 - val_mae: 0.0011

Epoch 472/600
17/17 0s 5ms/step - loss:
2.2037e-07 - mae: 2.2542e-04 - val_loss: 4.5258e-06 - val_mae: 0.0011

Epoch 473/600
17/17 0s 5ms/step - loss:
2.1915e-07 - mae: 2.2483e-04 - val_loss: 4.5160e-06 - val_mae: 0.0011

Epoch 474/600
17/17 0s 5ms/step - loss:
2.1673e-07 - mae: 2.2371e-04 - val_loss: 4.4292e-06 - val_mae: 0.0011

Epoch 475/600
17/17 0s 5ms/step - loss:
2.1905e-07 - mae: 2.2456e-04 - val_loss: 4.4777e-06 - val_mae: 0.0011

Epoch 476/600
17/17 0s 5ms/step - loss:
2.1668e-07 - mae: 2.2348e-04 - val_loss: 4.4702e-06 - val_mae: 0.0011

Epoch 477/600
17/17 0s 5ms/step - loss:
2.1414e-07 - mae: 2.2231e-04 - val_loss: 4.3861e-06 - val_mae: 0.0011

Epoch 478/600
17/17 0s 5ms/step - loss:
2.1645e-07 - mae: 2.2318e-04 - val_loss: 4.4347e-06 - val_mae: 0.0011

Epoch 479/600
17/17 0s 5ms/step - loss:
2.1416e-07 - mae: 2.2213e-04 - val_loss: 4.4283e-06 - val_mae: 0.0011

Epoch 480/600
17/17 0s 5ms/step - loss:
2.1152e-07 - mae: 2.2091e-04 - val_loss: 4.4074e-06 - val_mae: 0.0011

Epoch 481/600
17/17 0s 4ms/step - loss:
2.1252e-07 - mae: 2.2120e-04 - val_loss: 4.4017e-06 - val_mae: 0.0011

Epoch 482/600
17/17 0s 5ms/step - loss:
2.1133e-07 - mae: 2.2061e-04 - val_loss: 4.3939e-06 - val_mae: 0.0011

Epoch 483/600
17/17 0s 4ms/step - loss:
2.0885e-07 - mae: 2.1945e-04 - val_loss: 4.3123e-06 - val_mae: 0.0011

Epoch 484/600
17/17 0s 5ms/step - loss:
2.1118e-07 - mae: 2.2034e-04 - val_loss: 4.3588e-06 - val_mae: 0.0011

Epoch 485/600
17/17 0s 5ms/step - loss:
2.0896e-07 - mae: 2.1931e-04 - val_loss: 4.3524e-06 - val_mae: 0.0011

Epoch 486/600
17/17 0s 5ms/step - loss:
2.0689e-07 - mae: 2.1838e-04 - val_loss: 4.3401e-06 - val_mae: 0.0011

Epoch 487/600
17/17 0s 5ms/step - loss:
2.0705e-07 - mae: 2.1832e-04 - val_loss: 4.3322e-06 - val_mae: 0.0011

Epoch 488/600
17/17 0s 5ms/step - loss:
2.0500e-07 - mae: 2.1737e-04 - val_loss: 4.2933e-06 - val_mae: 0.0010

Epoch 489/600
17/17 0s 5ms/step - loss:
2.0547e-07 - mae: 2.1750e-04 - val_loss: 4.3275e-06 - val_mae: 0.0011

Epoch 490/600
17/17 0s 5ms/step - loss:
2.0380e-07 - mae: 2.1667e-04 - val_loss: 4.3137e-06 - val_mae: 0.0011

Epoch 491/600
17/17 0s 5ms/step - loss:
2.0269e-07 - mae: 2.1609e-04 - val_loss: 4.2598e-06 - val_mae: 0.0010

Epoch 492/600
17/17 0s 5ms/step - loss:
2.0251e-07 - mae: 2.1591e-04 - val_loss: 4.2272e-06 - val_mae: 0.0010

Epoch 493/600
17/17 0s 7ms/step - loss:
2.0285e-07 - mae: 2.1599e-04 - val_loss: 4.2650e-06 - val_mae: 0.0010

Epoch 494/600
17/17 0s 5ms/step - loss:
2.0098e-07 - mae: 2.1509e-04 - val_loss: 4.2547e-06 - val_mae: 0.0010

Epoch 495/600
17/17 0s 5ms/step - loss:
1.9904e-07 - mae: 2.1414e-04 - val_loss: 4.1768e-06 - val_mae: 0.0010

Epoch 496/600
17/17 0s 4ms/step - loss:
2.0102e-07 - mae: 2.1491e-04 - val_loss: 4.2176e-06 - val_mae: 0.0010

Epoch 497/600
17/17 0s 5ms/step - loss:
1.9907e-07 - mae: 2.1398e-04 - val_loss: 4.2103e-06 - val_mae: 0.0010

Epoch 498/600
17/17 0s 7ms/step - loss:
1.9695e-07 - mae: 2.1296e-04 - val_loss: 4.1357e-06 - val_mae: 0.0010

Epoch 499/600
17/17 0s 9ms/step - loss:
1.9894e-07 - mae: 2.1374e-04 - val_loss: 4.1774e-06 - val_mae: 0.0010

Epoch 500/600
17/17 0s 7ms/step - loss:
1.9699e-07 - mae: 2.1280e-04 - val_loss: 4.1716e-06 - val_mae: 0.0010

Epoch 501/600
17/17 0s 9ms/step - loss:
1.9477e-07 - mae: 2.1174e-04 - val_loss: 4.1526e-06 - val_mae: 0.0010

Epoch 502/600
17/17 0s 7ms/step - loss:
1.9563e-07 - mae: 2.1198e-04 - val_loss: 4.1476e-06 - val_mae: 0.0010

Epoch 503/600
17/17 0s 4ms/step - loss:
1.9459e-07 - mae: 2.1146e-04 - val_loss: 4.1408e-06 - val_mae: 0.0010

Epoch 504/600
17/17 0s 5ms/step - loss:
1.9251e-07 - mae: 2.1046e-04 - val_loss: 4.0688e-06 - val_mae: 0.0010

Epoch 505/600
17/17 0s 5ms/step - loss:
1.9449e-07 - mae: 2.1123e-04 - val_loss: 4.1091e-06 - val_mae: 0.0010

Epoch 506/600
17/17 0s 5ms/step - loss:
1.9260e-07 - mae: 2.1032e-04 - val_loss: 4.1037e-06 - val_mae: 0.0010

Epoch 507/600
17/17 0s 5ms/step - loss:
1.9067e-07 - mae: 2.0941e-04 - val_loss: 4.0699e-06 - val_mae: 0.0010

Epoch 508/600
17/17 0s 5ms/step - loss:
1.9115e-07 - mae: 2.0955e-04 - val_loss: 4.1014e-06 - val_mae: 0.0010

Epoch 509/600
17/17 0s 5ms/step - loss:
1.8942e-07 - mae: 2.0866e-04 - val_loss: 4.0538e-06 - val_mae: 0.0010

Epoch 510/600
17/17 0s 4ms/step - loss:
1.8954e-07 - mae: 2.0867e-04 - val_loss: 4.0836e-06 - val_mae: 0.0010

Epoch 511/600
17/17 0s 5ms/step - loss:
1.8811e-07 - mae: 2.0795e-04 - val_loss: 4.0715e-06 - val_mae: 0.0010

Epoch 512/600
17/17 0s 4ms/step - loss:
1.8678e-07 - mae: 2.0721e-04 - val_loss: 4.0155e-06 - val_mae: 0.0010

Epoch 513/600
17/17 0s 5ms/step - loss:
1.8772e-07 - mae: 2.0757e-04 - val_loss: 4.0464e-06 - val_mae: 0.0010

Epoch 514/600
17/17 0s 5ms/step - loss:
1.8619e-07 - mae: 2.0681e-04 - val_loss: 4.0356e-06 - val_mae: 0.0010

Epoch 515/600
17/17 0s 5ms/step - loss:
1.8453e-07 - mae: 2.0598e-04 - val_loss: 3.9648e-06 - val_mae: 0.0010

Epoch 516/600
17/17 0s 5ms/step - loss:
1.8634e-07 - mae: 2.0670e-04 - val_loss: 3.9997e-06 - val_mae: 0.0010

Epoch 517/600
17/17 0s 5ms/step - loss:
1.8466e-07 - mae: 2.0586e-04 - val_loss: 3.9924e-06 - val_mae: 0.0010

Epoch 518/600
17/17 0s 4ms/step - loss:
1.8281e-07 - mae: 2.0493e-04 - val_loss: 3.9251e-06 - val_mae: 0.0010

Epoch 519/600
17/17 0s 5ms/step - loss:
1.8463e-07 - mae: 2.0568e-04 - val_loss: 3.9613e-06 - val_mae: 0.0010

Epoch 520/600
17/17 0s 5ms/step - loss:
1.8295e-07 - mae: 2.0485e-04 - val_loss: 3.9559e-06 - val_mae: 0.0010

Epoch 521/600
17/17 0s 5ms/step - loss:
1.8121e-07 - mae: 2.0400e-04 - val_loss: 3.9245e-06 - val_mae: 0.0010

Epoch 522/600
17/17 0s 5ms/step - loss:
1.8165e-07 - mae: 2.0414e-04 - val_loss: 3.9533e-06 - val_mae: 0.0010

Epoch 523/600
17/17 0s 5ms/step - loss:
1.8008e-07 - mae: 2.0330e-04 - val_loss: 3.9092e-06 - val_mae: 9.9912e-04

Epoch 524/600
17/17 0s 5ms/step - loss:
1.8020e-07 - mae: 2.0334e-04 - val_loss: 3.9366e-06 - val_mae: 0.0010

Epoch 525/600
17/17 0s 4ms/step - loss:
1.7890e-07 - mae: 2.0266e-04 - val_loss: 3.9255e-06 - val_mae: 0.0010

Epoch 526/600
17/17 0s 5ms/step - loss:
1.7768e-07 - mae: 2.0195e-04 - val_loss: 3.8275e-06 - val_mae: 9.8868e-04

Epoch 527/600
17/17 0s 5ms/step - loss:
1.8008e-07 - mae: 2.0299e-04 - val_loss: 3.8661e-06 - val_mae: 9.9353e-04

Epoch 528/600
17/17 0s 5ms/step - loss:
1.7781e-07 - mae: 2.0193e-04 - val_loss: 3.8937e-06 - val_mae: 9.9696e-04

Epoch 529/600
17/17 0s 5ms/step - loss:
1.7648e-07 - mae: 2.0123e-04 - val_loss: 3.8834e-06 - val_mae: 9.9563e-04

Epoch 530/600
17/17 0s 5ms/step - loss:
1.7505e-07 - mae: 2.0049e-04 - val_loss: 3.8179e-06 - val_mae: 9.8729e-04

Epoch 531/600
17/17 0s 5ms/step - loss:
1.7661e-07 - mae: 2.0114e-04 - val_loss: 3.8493e-06 - val_mae: 9.9124e-04

Epoch 532/600
17/17 0s 4ms/step - loss:
1.7515e-07 - mae: 2.0039e-04 - val_loss: 3.8424e-06 - val_mae: 9.9033e-04

Epoch 533/600
17/17 0s 5ms/step - loss:
1.7354e-07 - mae: 1.9956e-04 - val_loss: 3.7803e-06 - val_mae: 9.8239e-04

Epoch 534/600
17/17 0s 5ms/step - loss:
1.7510e-07 - mae: 2.0021e-04 - val_loss: 3.8131e-06 - val_mae: 9.8653e-04

Epoch 535/600
17/17 0s 5ms/step - loss:
1.7362e-07 - mae: 1.9945e-04 - val_loss: 3.8080e-06 - val_mae: 9.8584e-04

Epoch 536/600
17/17 0s 5ms/step - loss:
1.7190e-07 - mae: 1.9857e-04 - val_loss: 3.7479e-06 - val_mae: 9.7813e-04

Epoch 537/600
17/17 0s 5ms/step - loss:
1.7349e-07 - mae: 1.9924e-04 - val_loss: 3.7812e-06 - val_mae: 9.8234e-04

Epoch 538/600
17/17 0s 4ms/step - loss:
1.7201e-07 - mae: 1.9848e-04 - val_loss: 3.7771e-06 - val_mae: 9.8178e-04

Epoch 539/600
17/17 0s 5ms/step - loss:
1.7120e-07 - mae: 1.9804e-04 - val_loss: 3.7716e-06 - val_mae: 9.8104e-04

Epoch 540/600
17/17 0s 5ms/step - loss:
1.6964e-07 - mae: 1.9722e-04 - val_loss: 3.7556e-06 - val_mae: 9.7893e-04

Epoch 541/600
17/17 0s 5ms/step - loss:
1.7021e-07 - mae: 1.9739e-04 - val_loss: 3.7510e-06 - val_mae: 9.7831e-04

Epoch 542/600
17/17 0s 5ms/step - loss:
1.6871e-07 - mae: 1.9663e-04 - val_loss: 3.7232e-06 - val_mae: 9.7470e-04

Epoch 543/600
17/17 0s 5ms/step - loss:
1.6907e-07 - mae: 1.9675e-04 - val_loss: 3.7493e-06 - val_mae: 9.7800e-04

Epoch 544/600
17/17 0s 5ms/step - loss:
1.6768e-07 - mae: 1.9600e-04 - val_loss: 3.7101e-06 - val_mae: 9.7293e-04

Epoch 545/600
17/17 0s 5ms/step - loss:
1.6779e-07 - mae: 1.9601e-04 - val_loss: 3.7348e-06 - val_mae: 9.7607e-04

Epoch 546/600
17/17 0s 5ms/step - loss:
1.6634e-07 - mae: 1.9522e-04 - val_loss: 3.6762e-06 - val_mae: 9.6847e-04

Epoch 547/600
17/17 0s 4ms/step - loss:
1.6722e-07 - mae: 1.9558e-04 - val_loss: 3.7040e-06 - val_mae: 9.7204e-04

Epoch 548/600
17/17 0s 5ms/step - loss:
1.6573e-07 - mae: 1.9479e-04 - val_loss: 3.6674e-06 - val_mae: 9.6727e-04

Epoch 549/600
17/17 0s 5ms/step - loss:
1.6584e-07 - mae: 1.9481e-04 - val_loss: 3.6930e-06 - val_mae: 9.7054e-04

Epoch 550/600
17/17 0s 5ms/step - loss:
1.6433e-07 - mae: 1.9399e-04 - val_loss: 3.6368e-06 - val_mae: 9.6321e-04

Epoch 551/600
17/17 0s 5ms/step - loss:
1.6521e-07 - mae: 1.9436e-04 - val_loss: 3.6650e-06 - val_mae: 9.6683e-04

Epoch 552/600
17/17 0s 5ms/step - loss:
1.6307e-07 - mae: 1.9326e-04 - val_loss: 3.6092e-06 - val_mae: 9.5954e-04

Epoch 553/600
17/17 0s 5ms/step - loss:
1.6449e-07 - mae: 1.9387e-04 - val_loss: 3.6393e-06 - val_mae: 9.6342e-04

Epoch 554/600
17/17 0s 5ms/step - loss:
1.6315e-07 - mae: 1.9317e-04 - val_loss: 3.6352e-06 - val_mae: 9.6285e-04

Epoch 555/600
17/17 0s 5ms/step - loss:
1.6158e-07 - mae: 1.9234e-04 - val_loss: 3.5808e-06 - val_mae: 9.5571e-04

Epoch 556/600
17/17 0s 5ms/step - loss:
1.6302e-07 - mae: 1.9297e-04 - val_loss: 3.6111e-06 - val_mae: 9.5965e-04

Epoch 557/600
17/17 0s 4ms/step - loss:
1.6170e-07 - mae: 1.9227e-04 - val_loss: 3.6076e-06 - val_mae: 9.5917e-04

Epoch 558/600
17/17 0s 5ms/step - loss:
1.6098e-07 - mae: 1.9185e-04 - val_loss: 3.6030e-06 - val_mae: 9.5851e-04

Epoch 559/600
17/17 0s 5ms/step - loss:
1.5955e-07 - mae: 1.9110e-04 - val_loss: 3.5884e-06 - val_mae: 9.5654e-04

Epoch 560/600
17/17 0s 5ms/step - loss:
1.6009e-07 - mae: 1.9126e-04 - val_loss: 3.5845e-06 - val_mae: 9.5601e-04

Epoch 561/600
17/17 0s 5ms/step - loss:
1.5885e-07 - mae: 1.9064e-04 - val_loss: 3.5770e-06 - val_mae: 9.5499e-04

Epoch 562/600
17/17 0s 5ms/step - loss:
1.5892e-07 - mae: 1.9059e-04 - val_loss: 3.5721e-06 - val_mae: 9.5431e-04

Epoch 563/600
17/17 0s 5ms/step - loss:
1.5766e-07 - mae: 1.8993e-04 - val_loss: 3.5465e-06 - val_mae: 9.5091e-04

Epoch 564/600
17/17 0s 7ms/step - loss:
1.5795e-07 - mae: 1.9001e-04 - val_loss: 3.5693e-06 - val_mae: 9.5387e-04

Epoch 565/600
17/17 0s 5ms/step - loss:
1.5676e-07 - mae: 1.8934e-04 - val_loss: 3.5337e-06 - val_mae: 9.4915e-04

Epoch 566/600
17/17 0s 4ms/step - loss:
1.5686e-07 - mae: 1.8937e-04 - val_loss: 3.5556e-06 - val_mae: 9.5201e-04

Epoch 567/600
17/17 0s 4ms/step - loss:
1.5560e-07 - mae: 1.8865e-04 - val_loss: 3.5026e-06 - val_mae: 9.4496e-04

Epoch 568/600
17/17 0s 7ms/step - loss:
1.5638e-07 - mae: 1.8899e-04 - val_loss: 3.5273e-06 - val_mae: 9.4818e-04

Epoch 569/600
17/17 0s 5ms/step - loss:
1.5508e-07 - mae: 1.8828e-04 - val_loss: 3.4941e-06 - val_mae: 9.4377e-04

Epoch 570/600
17/17 0s 5ms/step - loss:
1.5519e-07 - mae: 1.8830e-04 - val_loss: 3.5170e-06 - val_mae: 9.4678e-04

Epoch 571/600
17/17 0s 5ms/step - loss:
1.5387e-07 - mae: 1.8754e-04 - val_loss: 3.4663e-06 - val_mae: 9.3999e-04

Epoch 572/600
17/17 0s 5ms/step - loss:
1.5464e-07 - mae: 1.8788e-04 - val_loss: 3.4914e-06 - val_mae: 9.4330e-04

Epoch 573/600
17/17 0s 7ms/step - loss:
1.5278e-07 - mae: 1.8688e-04 - val_loss: 3.4410e-06 - val_mae: 9.3655e-04

Epoch 574/600
17/17 0s 5ms/step - loss:
1.5402e-07 - mae: 1.8744e-04 - val_loss: 3.4679e-06 - val_mae: 9.4011e-04

Epoch 575/600
17/17 0s 7ms/step - loss:
1.5284e-07 - mae: 1.8680e-04 - val_loss: 3.4641e-06 - val_mae: 9.3958e-04

Epoch 576/600
17/17 0s 5ms/step - loss:
1.5147e-07 - mae: 1.8605e-04 - val_loss: 3.4507e-06 - val_mae: 9.3774e-04

Epoch 577/600
17/17 0s 5ms/step - loss:
1.5201e-07 - mae: 1.8625e-04 - val_loss: 3.4476e-06 - val_mae: 9.3729e-04

Epoch 578/600
17/17 0s 5ms/step - loss:
1.5102e-07 - mae: 1.8574e-04 - val_loss: 3.4667e-06 - val_mae: 9.3981e-04

Epoch 579/600
17/17 0s 5ms/step - loss:
1.5001e-07 - mae: 1.8515e-04 - val_loss: 3.4319e-06 - val_mae: 9.3514e-04

Epoch 580/600
17/17 0s 8ms/step - loss:
1.4989e-07 - mae: 1.8503e-04 - val_loss: 3.4094e-06 - val_mae: 9.3206e-04

Epoch 581/600
17/17 0s 9ms/step - loss:
1.5016e-07 - mae: 1.8512e-04 - val_loss: 3.4313e-06 - val_mae: 9.3498e-04

Epoch 582/600
17/17 0s 9ms/step - loss:
1.4920e-07 - mae: 1.8458e-04 - val_loss: 3.4246e-06 - val_mae: 9.3405e-04

Epoch 583/600
17/17 0s 8ms/step - loss:
1.4854e-07 - mae: 1.8418e-04 - val_loss: 3.3925e-06 - val_mae: 9.2971e-04

Epoch 584/600
17/17 0s 9ms/step - loss:
1.4841e-07 - mae: 1.8404e-04 - val_loss: 3.3721e-06 - val_mae: 9.2693e-04

Epoch 585/600
17/17 0s 6ms/step - loss:
1.4863e-07 - mae: 1.8411e-04 - val_loss: 3.3950e-06 - val_mae: 9.2999e-04

Epoch 586/600
17/17 0s 5ms/step - loss:
1.4761e-07 - mae: 1.8354e-04 - val_loss: 3.3896e-06 - val_mae: 9.2921e-04

Epoch 587/600
17/17 0s 5ms/step - loss:
1.4647e-07 - mae: 1.8290e-04 - val_loss: 3.3415e-06 - val_mae: 9.2268e-04

Epoch 588/600
17/17 0s 5ms/step - loss:
1.4762e-07 - mae: 1.8342e-04 - val_loss: 3.3658e-06 - val_mae: 9.2595e-04

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Epoch 589/600
17/17          0s 5ms/step - loss:
1.4656e-07 - mae: 1.8283e-04 - val_loss: 3.3618e-06 - val_mae: 9.2538e-04
Epoch 590/600
17/17          0s 4ms/step - loss:
1.4532e-07 - mae: 1.8214e-04 - val_loss: 3.3154e-06 - val_mae: 9.1903e-04
Epoch 591/600
17/17          0s 5ms/step - loss:
1.4649e-07 - mae: 1.8268e-04 - val_loss: 3.3402e-06 - val_mae: 9.2238e-04
Epoch 592/600
17/17          0s 5ms/step - loss:
1.4542e-07 - mae: 1.8208e-04 - val_loss: 3.3371e-06 - val_mae: 9.2193e-04
Epoch 593/600
17/17          0s 5ms/step - loss:
1.4484e-07 - mae: 1.8176e-04 - val_loss: 3.3330e-06 - val_mae: 9.2135e-04
Epoch 594/600
17/17          0s 7ms/step - loss:
1.4370e-07 - mae: 1.8110e-04 - val_loss: 3.2876e-06 - val_mae: 9.1512e-04
Epoch 595/600
17/17          0s 5ms/step - loss:
1.4480e-07 - mae: 1.8160e-04 - val_loss: 3.3119e-06 - val_mae: 9.1841e-04
Epoch 596/600
17/17          0s 5ms/step - loss:
1.4374e-07 - mae: 1.8101e-04 - val_loss: 3.3087e-06 - val_mae: 9.1793e-04
Epoch 597/600
17/17          0s 5ms/step - loss:
1.4254e-07 - mae: 1.8034e-04 - val_loss: 3.2966e-06 - val_mae: 9.1624e-04
Epoch 598/600
17/17          0s 6ms/step - loss:
1.4301e-07 - mae: 1.8051e-04 - val_loss: 3.2937e-06 - val_mae: 9.1582e-04
Epoch 599/600
17/17          0s 5ms/step - loss:
1.4212e-07 - mae: 1.8003e-04 - val_loss: 3.3113e-06 - val_mae: 9.1820e-04
Epoch 600/600
17/17          0s 5ms/step - loss:
1.4098e-07 - mae: 1.7935e-04 - val_loss: 3.2422e-06 - val_mae: 9.0868e-04

```

3.4 Verify

Graph the models performance vs validation.

3.4.1 Graph the loss

Graph the loss to see when the model stops improving.

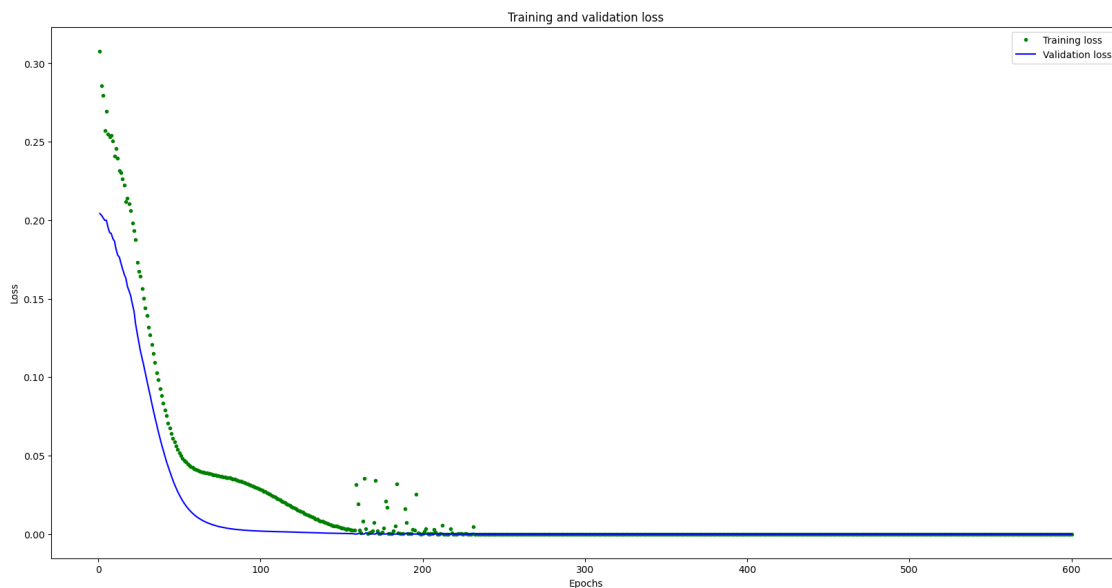
```

[6]: # increase the size of the graphs. The default size is (6,4).
plt.rcParams["figure.figsize"] = (20,10)

```

```
# graph the loss, the model above is configure to use "mean squared error" as
↳ the loss function
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(loss) + 1)
plt.plot(epochs, loss, 'g.', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.show()

print(plt.rcParams["figure.figsize"])
```



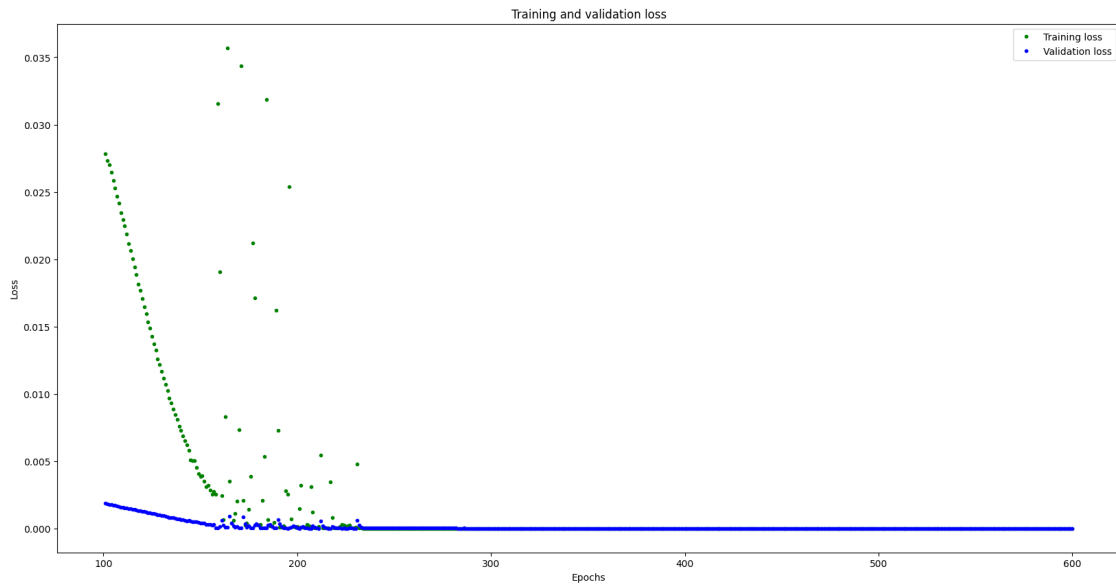
[20.0, 10.0]

3.4.2 Graph the loss again, skipping a bit of the start

We'll graph the same data as the previous code cell, but start at index 100 so we can further zoom in once the model starts to converge.

```
[7]: # graph the loss again skipping a bit of the start
SKIP = 100
plt.plot(epochs[SKIP:], loss[SKIP:], 'g.', label='Training loss')
plt.plot(epochs[SKIP:], val_loss[SKIP:], 'b.', label='Validation loss')
plt.title('Training and validation loss')
plt.xlabel('Epochs')
```

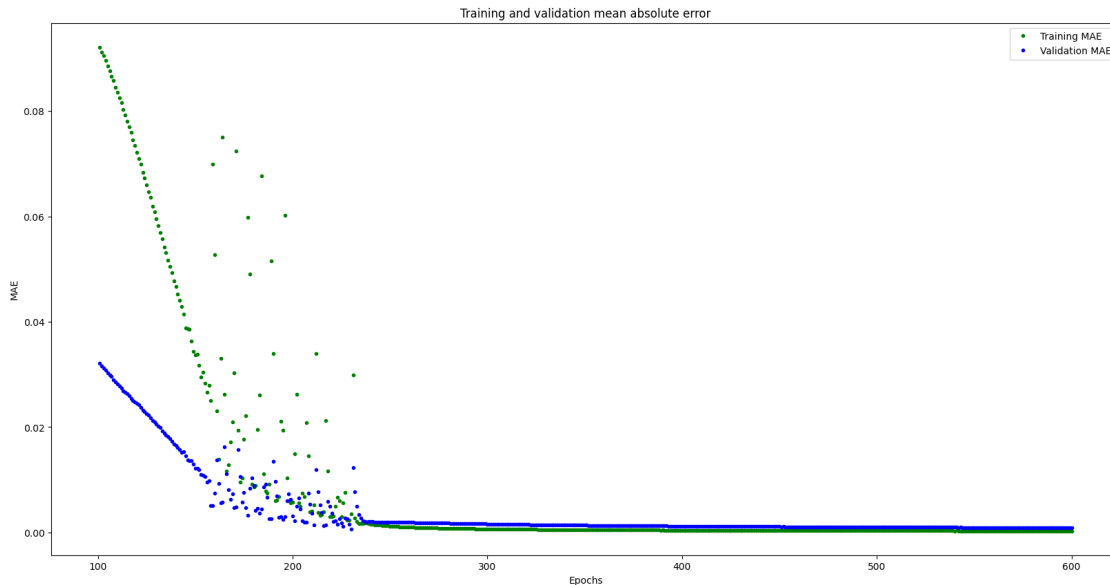
```
plt.ylabel('Loss')
plt.legend()
plt.show()
```



3.4.3 Graph the mean absolute error

Mean absolute error is another metric to judge the performance of the model.

```
[8]: # graph of mean absolute error
mae = history.history['mae']
val_mae = history.history['val_mae']
plt.plot(epochs[SKIP:], mae[SKIP:], 'g.', label='Training MAE')
plt.plot(epochs[SKIP:], val_mae[SKIP:], 'b.', label='Validation MAE')
plt.title('Training and validation mean absolute error')
plt.xlabel('Epochs')
plt.ylabel('MAE')
plt.legend()
plt.show()
```

3.4.4 Run with Test Data

Put our test data into the model and plot the predictions

```
[9]: # use the model to predict the test inputs
predictions = model.predict(inputs_test)

# print the predictions and the expected outputs
print("predictions =\n", np.round(predictions, decimals=3))
print("actual =\n", outputs_test)

# Plot the predictions along with to the test data
plt.clf()
plt.title('Training data predicted vs actual values')
plt.plot(inputs_test, outputs_test, 'b.', label='Actual')
plt.plot(inputs_test, predictions, 'r.', label='Predicted')
plt.show()
```

1/1 0s 108ms/step

```
predictions =
[[0.932 0.068]
 [0.999 0.001]
 [1.    0.   ]
 [0.    1.   ]
 [0.    1.   ]]
actual =
[[1. 0.]
 [1. 0.]
```

```
[1. 0.]
[0. 1.]
[0. 1.]]
```

```
-----
ValueError                                Traceback (most recent call last)
<ipython-input-9-797f8421ff49> in <cell line: 0>()
      9 plt.clf()
     10 plt.title('Training data predicted vs actual values')
--> 11 plt.plot(inputs_test, outputs_test, 'b.', label='Actual')
     12 plt.plot(inputs_test, predictions, 'r.', label='Predicted')
     13 plt.show()

/usr/local/lib/python3.11/dist-packages/matplotlib/pyplot.py in plot(scalex,
↳ scaley, data, *args, **kwargs)
     3827     **kwargs,
     3828 ) -> list[Line2D]:
-> 3829     return gca().plot(

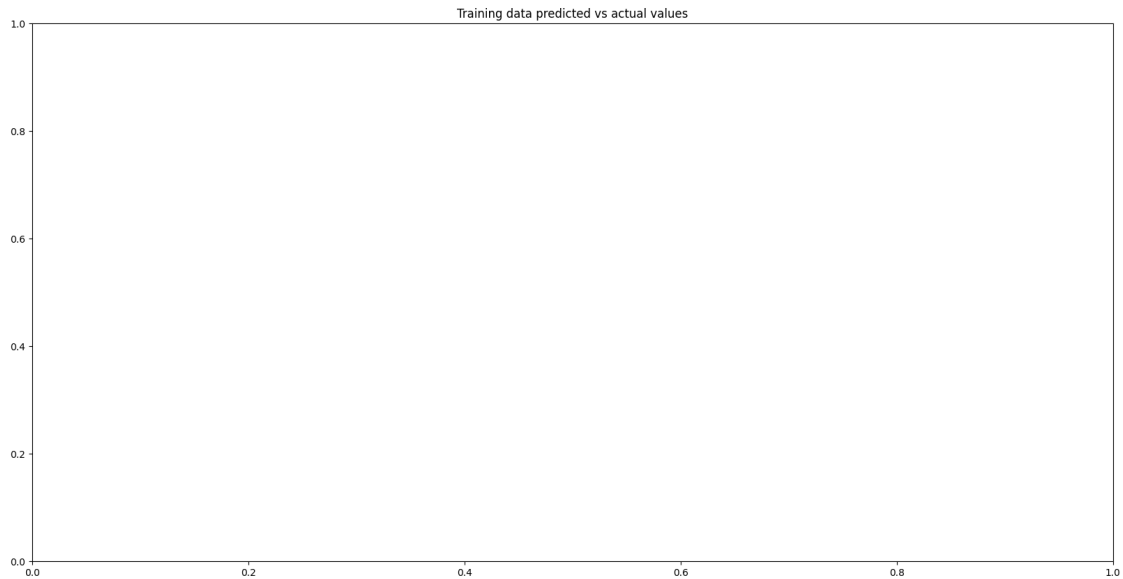
     3830         *args,
     3831         scalex=scalex,

/usr/local/lib/python3.11/dist-packages/matplotlib/axes/_axes.py in plot(self,
↳ scalex, scaley, data, *args, **kwargs)
     1775         """
     1776         kwargs = cbook.normalize_kwargs(kwargs, mlines.Line2D)
-> 1777         lines = [*self._get_lines(self, *args, data=data, **kwargs)]
     1778         for line in lines:
     1779             self.add_line(line)

/usr/local/lib/python3.11/dist-packages/matplotlib/axes/_base.py in
↳ __call__(self, axes, data, return_kwargs, *args, **kwargs)
     295         this += args[0],
     296         args = args[1:]
-> 297         yield from self._plot_args(
     298             axes, this, kwargs,
↳ ambiguous_fmt_datakey=ambiguous_fmt_datakey,
     299             return_kwargs=return_kwargs

/usr/local/lib/python3.11/dist-packages/matplotlib/axes/_base.py in
↳ _plot_args(self, axes, tup, kwargs, return_kwargs, ambiguous_fmt_datakey)
     514         ncx, ncy = x.shape[1], y.shape[1]
     515         if ncx > 1 and ncy > 1 and ncx != ncy:
-> 516             raise ValueError(f"x has {ncx} columns but y has {ncy}
↳ columns")
     517         if ncx == 0 or ncy == 0:
     518             return []
```

ValueError: x has 714 columns but y has 2 columns



4 Convert the Trained Model to Tensor Flow Lite

The next cell converts the model to TFlite format. The size in bytes of the model is also printed out.

```
[10]: # Convert the model to the TensorFlow Lite format without quantization
converter = tf.lite.TFLiteConverter.from_keras_model(model)
tflite_model = converter.convert()

# Save the model to disk
open("gesture_model.tflite", "wb").write(tflite_model)

import os
basic_model_size = os.path.getsize("gesture_model.tflite")
print("Model is %d bytes" % basic_model_size)
```

Saved artifact at '/tmp/tmpabcak2ke'. The following endpoints are available:

* Endpoint 'serve'

args_0 (POSITIONAL_ONLY): TensorSpec(shape=(1, 714), dtype=tf.float32, name='keras_tensor')

Output Type:

TensorSpec(shape=(1, 2), dtype=tf.float32, name=None)

Captures:

135054481013264: TensorSpec(shape=(), dtype=tf.resource, name=None)

135054481014416: TensorSpec(shape=(), dtype=tf.resource, name=None)

```
135054481014608: TensorSpec(shape=(), dtype=tf.resource, name=None)
135054481013456: TensorSpec(shape=(), dtype=tf.resource, name=None)
135054479344080: TensorSpec(shape=(), dtype=tf.resource, name=None)
135054479345232: TensorSpec(shape=(), dtype=tf.resource, name=None)
Model is 148188 bytes
```

4.1 Encode the Model in an Arduino Header File

The next cell creates a constant byte array that contains the TFlite model. Import it as a tab with the sketch below.

```
[11]: !echo "const unsigned char model[] = {" > /content/model.h
!cat gesture_model.tflite | xxd -i      >> /content/model.h
!echo "};"                             >> /content/model.h

import os
model_h_size = os.path.getsize("model.h")
print(f"Header file, model.h, is {model_h_size:,} bytes.")
print("\nOpen the side panel (refresh if needed). Double click model.h to ↵
↳download the file.")
```

Header file, model.h, is 913,860 bytes.

Open the side panel (refresh if needed). Double click model.h to download the file.

5 Classifying IMU Data

Now it's time to switch back to the tutorial instructions and run our new model on the Arduino Nano 33 BLE Sense to classify the accelerometer and gyroscope data.