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ME 249 Project 4 Report

For Project 4, I worked on all of the tasks by myself. This project looked at the performance of the boiler design in the PS10 solar thermal power plant (Task 1), and the natural convection cooling of discrete heated electronic components mounted on a vertical circuit board (Task 2).

Task 1

In task 1.1, I was given operating and performance parameter data for the boiler design as ME248Proj4data1a data array. Each of the three input parameters—D_i, q_0'', $\dot{m}$—and the two output parameters (x_e, $T_{w,\,max}$) were standardized by dividing by the median value of each respective parameter. The normalized data was randomly separated to create a training set (3/4 the size of the data) and a validation set (1/4 the size of the data). Then, I created the keras sequential network model with the following specs— 1) RandomUniform initializer, 2) inlet layer with 6 neurons (with 3 inputs) with K.elu activation function, 3) 3 hidden layers with 8, 16, and 8 neurons all with K.elu activation function, 4) outlet layer with 2 neurons without an activation function, 5) RMSprop optimizer, 6) initialized weights to -0.2 and 0.5, 7) epochs of 800, and 8) learning rate of 0.005. The resulting NN model was trained to get the mean absolute error of 0.025 or below (ended up getting MAE = 0.0124137 with best epoch at 651).

After the training is complete, I ran two comparisons sets—first between the prediction vs real data from the training data set (Figure 1), and second between the prediction vs real data from the normalized validation data set (Figure 2) both for the exit quality. The mean absolute error between the prediction and the training set was 0.02351 while the mean absolute error between the prediction and the normalized validation set was 0.02903. Therefore, both predictions were good using the trained model, but it was visible that trained set predictions were slightly better than the validation set predictions. It makes sense since the model was actually trained based on the training set—the model has seen these values before, so it should be better at predicting the exit quality output given the training set. There was no sign of overfitting since the both the loss and predictions from the training and validation set predictions (in respect to the real data) are about the same.

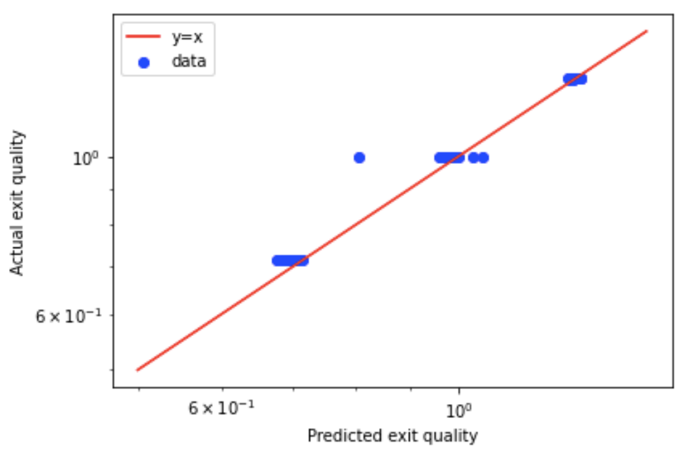

Figure 1. A log-log scatter plot of exit quality prediction vs given data for trained data using the keras model. It makes a good prediction as can be seen on the graph. The MAE was 0.02351. The red line is a reference linear line (actual = prediction; ie, y = x).

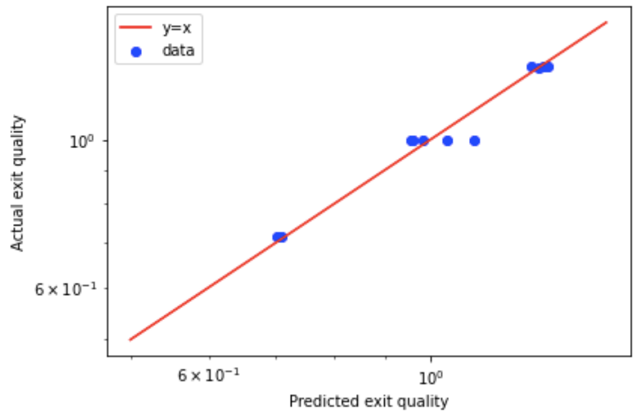

Figure 2. A log-log scatter plot of exit quality prediction vs given data from the validation set using the trained keras model. It makes a good prediction, similar to the trained set (Figure 1) as can be seen on the graph. The MAE was 0.02903. The red line is a reference linear line (actual = prediction; ie, y = x).

The keras model from above was used to create surface plots (Figure 3) of exit quality (x_e) and maximum wall temperature ($T_{w,\,max}$) predictions based on the function of D_i and $\dot{m}$. Solar flux was fixed at 750 kW/m^2 while $7\ mm < D_i < 13\ mm$ and $0.05 < \dot{m} < 0.15\ kg/s$. Based on the surface plot, if you want to get an output quality of about 0.75 and a maximum wall temperature no more than about 310 °C, I would recommend the parameter values of $q_0^{"} = 750\frac{kW}{m^2},\ D_i = 0.0105\ \text{m}, \text{and}\ \dot{m} = 0.014\frac{kg}{s}$.

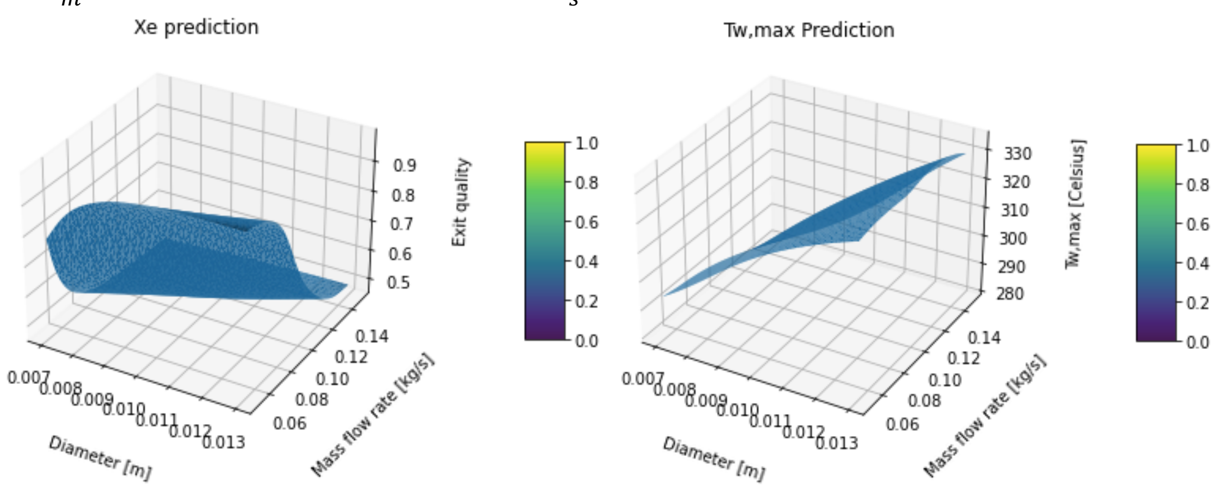

Figure 3. Surface plots for predicted x_e and $T_{w,\,max}$ values for $7\ mm < D_i < 13\ mm$ and $0.05 < \dot{m} < 0.15\ kg/s$ with $q_0^{"} = 750\ kW/m^2$. To get an x_e = 0.75 and a maximum wall temperature ≤ 310 °C, I would recommend the parameter values of $q_0^{"} = 750\frac{kW}{m^2},\ D_i = 0.0105\ m, and\ \dot{m} = 0.014\frac{kg}{s}$.

In task 1.2, I repeated task 1.1 with a new neural network model. The sequential neural network model now has the following specs— 1) RandomUniform initializer, 2) inlet layer with 6 neurons (with 3 inputs) with K.elu activation function, 3) 4 hidden layers with 8, 12, 16, and 8 neurons all with K.elu activation function, 4) dropout layers of the value of 0.25 after each of the four hidden layers, 5) outlet layer with 2 neurons without an activation function, 6) RMSprop optimizer, 7) initialized weights to -0.2 and 0.5, 8) epochs of 800, and 9) learning rate of 0.001. The resulting NN model was trained to get MAE = 0.045224 with best epoch at 190). After the training is complete, I ran two comparisons sets—first between the prediction vs real data from the training data set (Figure 4), and second between the prediction vs real data from the normalized validation data set (Figure 5 both for the exit quality. The mean absolute error between the prediction and the training set was 0.02351 while the mean absolute error between the prediction and the normalized validation set was 0.02903. Therefore, both predictions were good using the trained model, but it was visible that trained set predictions were slightly better than the validation set predictions. It makes sense since the model was actually trained based on the training set—the model has seen these values before, so it should be better at predicting the exit quality output given the training set. There was no sign of overfitting since the both the loss and predictions from the training and validation set predictions (in respect to the real data) are about the same. Compared to the results from Task 1.1, the predictions for Task 1.2 were similar to Task 1.1 with the dropout layers. Since there was no overfitting initially in Task1.1, it is expected that the dropout layers would have little to no effect. The fit to the training and validation data are similar as before.

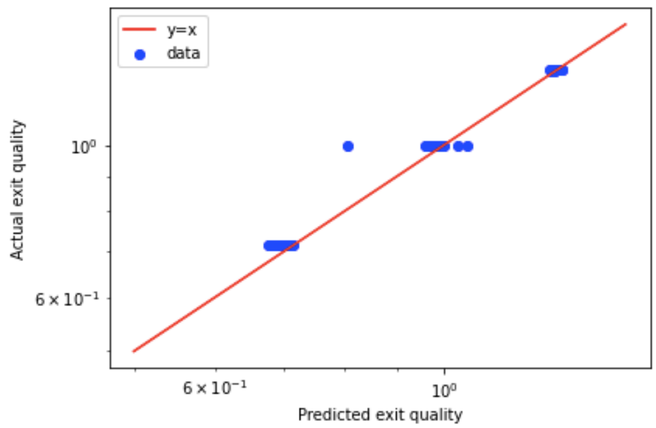

Figure 4. A log-log scatter plot of exit quality prediction vs given data for trained data using the keras model. It makes a good prediction as can be seen on the graph. The MAE was 0.02351. The red line is a reference linear line (actual = prediction; ie, y = x). It gives a similar result as the model from Task 1.1.

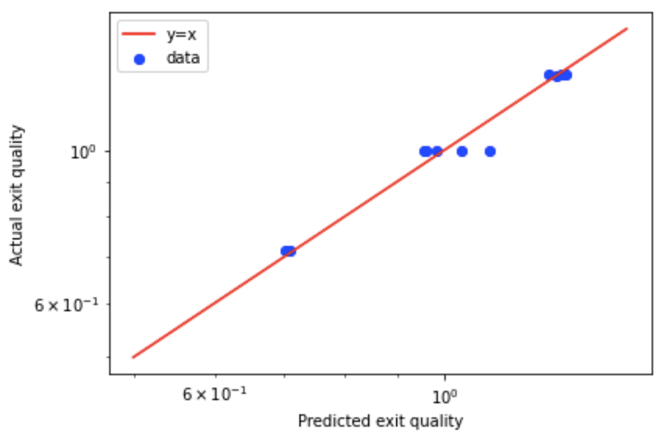

Figure 5. A log-log scatter plot of exit quality prediction vs given data from the validation set using the trained keras model. It makes a good prediction, similar to the trained set (Figure 4) as can be seen on the graph. The MAE was 0.02903. The red line is a reference linear line (actual = prediction; ie, y = x). It gives a similar result as the model from Task 1.1.

The keras model from above was used to create surface plots (Figure 6) of exit quality (x_e) and maximum wall temperature ($T_{w,\,max}$) predictions based on the function of D_i and $\dot{m}$.

Solar flux was fixed at 750 kW/m^2 while $7\ mm < D_i < 13\ mm$ and $0.05 < \dot{m} < 0.15\ kg/s$. Based on the surface plot, if you want to get an output quality of about 0.75 and a maximum wall temperature no more than about 310 ℃, I would recommend the parameter values of $q_0'' = 750\frac{kW}{m^2},\ D_i = 0.0105$ m, and $\dot{m} = 0.014\frac{kg}{s}$. Both the surface plots and parameter value recommendations validate the values from Task1.1.

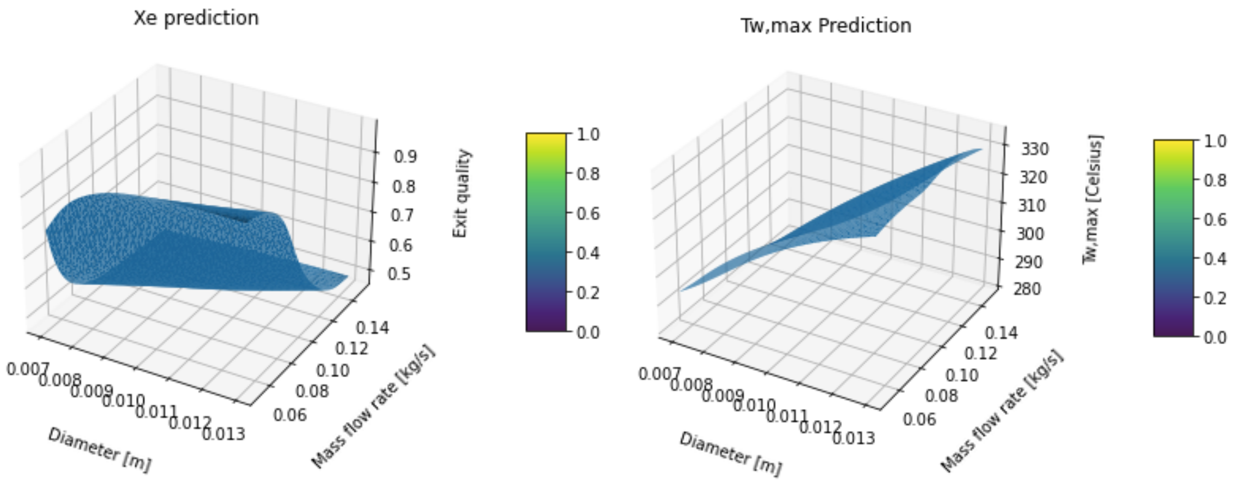

Figure 6. Surface plots for predicted x_e and $T_{w,\max}$ values for $7\ mm < D_i < 13\ mm$ and $0.05 < \dot{m} < 0.15\ kg/s$ with $q_0'' = 750\ kW/m^2$. To get an $x_e = 0.75$ and a maximum wall temperature ≤ 310 ℃, I would recommend the parameter values of $q_0'' = 750\frac{kW}{m^2},\ D_i = 0.0105\ m, and\ \dot{m} = 0.014\frac{kg}{s}$. The plots and the parameter recommendation values are similar to and validates the results from Task1.1.

In task 1.3, I was given a second set of operating and performance parameter data for the boiler design as ME248Proj4data1b data array. Each of the four input parameters—D_i, q_0'', x_e, $T_{w,max}$—and the output parameter ($\dot{m}$) were standardized by dividing by the median value of each respective parameter. The normalized data was randomly separated to create a training set (3/4 the size of the data) and a validation set (1/4 the size of the data). Then, I created the keras sequential network model with the following specs— 1) RandomUniform initializer, 2) inlet layer with 8 neurons (with 4 inputs) with K.elu activation function, 3) 3 hidden layers with 16, 16, and 16 neurons all with K.elu activation function, 4) outlet layer with 1 neuron without an activation function, 5) no dropout layers, 6) RMSprop optimizer, 7) initialized weights to -0.2 and 0.5, 8) epochs of 800, and 8) learning rate of 0.001. The resulting NN model was trained to get the mean absolute error of 0.025 or below (ended up getting MAE = 0.019651 with best epoch at 778).

After the training is complete, I ran two comparisons sets—first between the prediction vs real data from the training data set (Figure 7), and second between the prediction vs real data from the normalized validation data set (Figure 8) both for the mass flow rate. The mean absolute error between the prediction and the training set was 0.030806 while the mean absolute error between the prediction and the normalized validation set was 0.0291495. Therefore, both predictions were good using the trained model. In this case, the validation set was slightly better than the trained set predictions, which is counterintuitive, but it was similar enough that we can say it is not a significant difference.

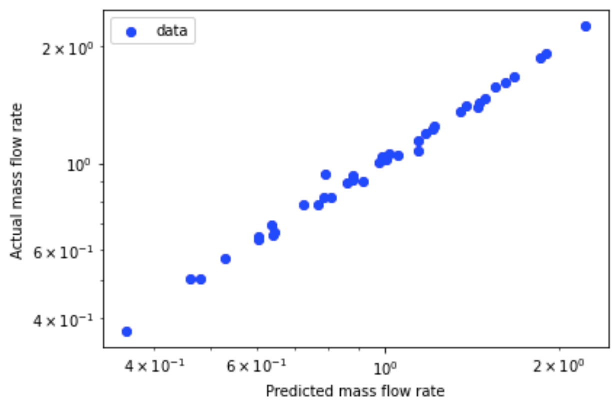

Figure 7. A log-log scatter plot of mass flow rate prediction vs given data for trained data using the keras model. It makes a good prediction as can be seen on the graph. The MAE was 0.030806.

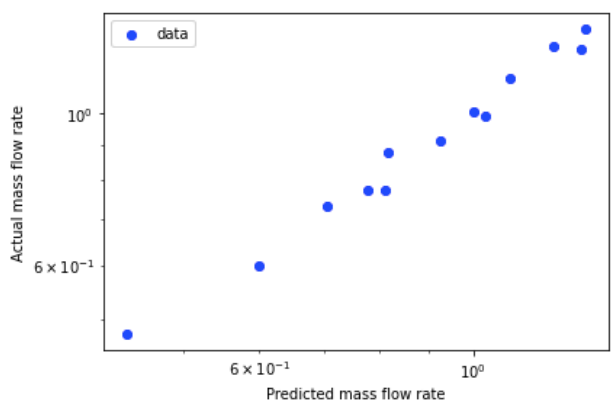

Figure 8. A log-log scatter plot of mass flow rate prediction vs given data from the validation set using the trained keras model. It makes a good prediction, similar to the trained set (Figure 7) as can be seen on the graph. The MAE was 0.0291495. The validation set MAE was slightly better than the trained set predictions, which is counterintuitive, but it was similar enough that we can say it is not a significant difference.

The keras model from above was used to create a plot (Figure 9) of mass flow rate ($\dot{m}$) prediction vs solar flux (q_0''). Tube inside diameter (D_i) was fixed at $0.010\ m$, exit quality (x_e) fixed at 0.70, and $T_{w,\ max}$ fixed at 300 °C, while $500 < q_0'' < 800\ kW/m^2$.

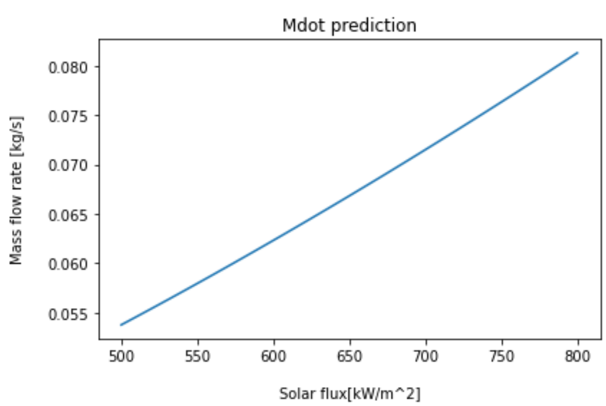

Figure 9. A plot of $\dot{m}$ prediction vs q_0'' for $D_i = 0.010\ m$, $x_e = 0.70$, $T_{w,\ max} = 300$ °C, and $500 < q_0'' < 800\ kW/m^2$.

Task 2

In task 2, I am looking at natural convection cooling of two discrete heated electronic components mounted on a vertical circuit board as shown in Figure 10. The performance data of the system generated by a CFD-type model is given as ME249Proj4data2 with the input data [q_1'', q_2'', Δx_s] and the output parameter [$T_{s,\,max}$].

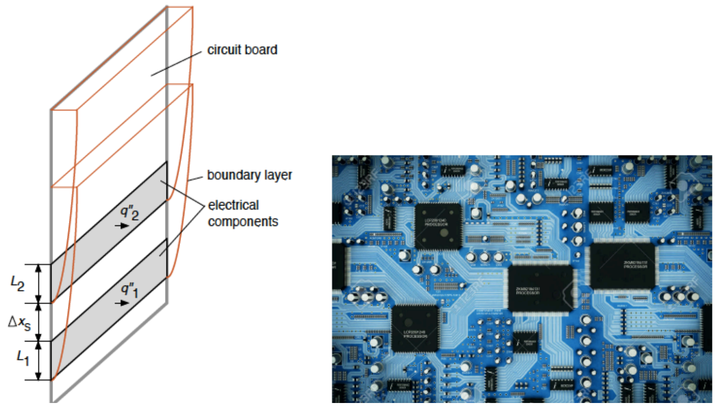

Figure 10. Schematics of the electronic components mounted on a vertical circuit board.

In task 2.1, I normalized the CFD-generated performance parameter data of the system above for each of the three input parameters—q_1'', q_2'', Δx_s—and the output parameter ($T_{s,\,max}$) by dividing by the median value of each respective parameter. The normalized data was randomly separated to create a training set (3/4 the size of the data) and a validation set (1/4 the size of the data). Then, I created the keras sequential network model with the following specs— 1) RandomUniform initializer, 2) inlet layer with 8 neurons (with 3 inputs) with K.elu activation function, 3) 3 hidden layers with 16, 16, and 16 neurons all with K.elu activation function, 4) outlet layer with 1 neuron without an activation function, 5) no dropout layers, 6) RMSprop optimizer, 7) initialized weights to -0.2 and 0.5, 8) epochs of 800, and 8) learning rate of 0.001. The resulting NN model was trained to get MAE = 0.029722 with best epoch at 430.

After the training is complete, I ran two comparisons sets—first between the prediction vs real data from the training data set (Figure 11), and second between the prediction vs real data from the normalized validation data set (Figure 12) both for the maximum surface temperature ($T_{s,\,max}$). The mean absolute error between the prediction and the training set was 0.0407531 while the mean absolute error between the prediction and the normalized validation set was 0.074538. Therefore, both predictions were good using the trained model, but it was visible that trained set predictions were slightly better than the validation set predictions. It makes sense since the model was actually trained based on the training set—the model has seen these values before, so it should be better at predicting the maximum surface temperature output given the training set.

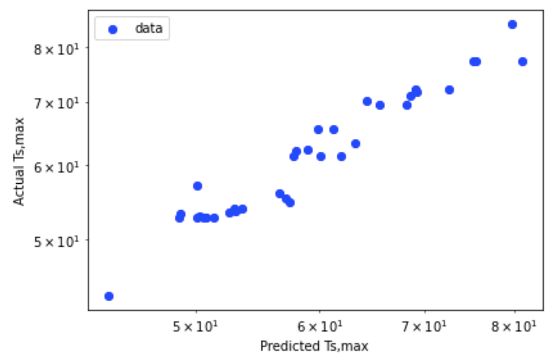

Figure 11. A log-log scatter plot of $T_{s,\,max}$ prediction vs given data for trained data using the keras model. It makes a fairly good prediction as can be seen on the graph. The MAE was 0.0407531.

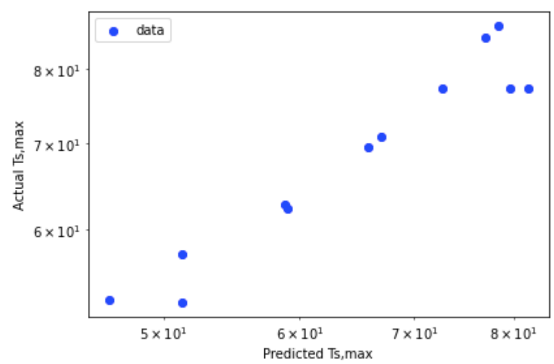

Figure 12. A log-log scatter plot of $T_{s,\,max}$ prediction vs given data from the validation set using the trained keras model. It makes a good prediction with respect to the actual value as can be seen on the graph. The MAE was 0.074538.

The keras model from above was used to create surface plots (Figure 13) of the maximum surface temperature ($T_{s,\,max}$) prediction based on the function of $q''_{2\&3}$ and Δx_s. The heat flux was $100 < q''_{2\&3} < 500\ W/m^2$ while $0.0 < \Delta x_s < 0.015\ m$. Based on the surface plot, if you want to get a maximum surface temperature no more than about 75 ℃, I would recommend the parameter values of $q''_{2\&3} < 467\,\frac{W}{m^2}$, and $\Delta x_s < 0.002755\ m$.

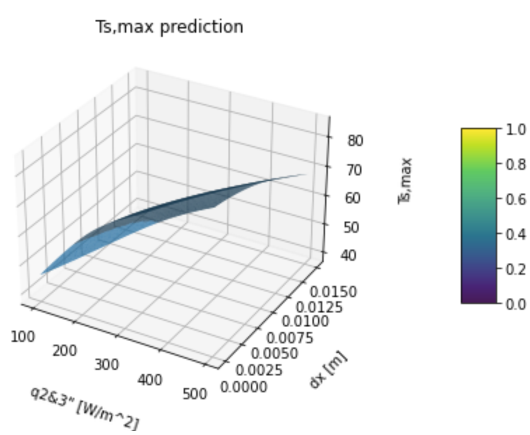

Figure 13. A surface plot for predicted $T_{s,\,max}$ value for $100 < q''_{2\&3} < 500\ W/m^2$ and $0.0 < \Delta x_s < 0.015\ m$. To get $T_{s,\,max} \leq 75$ ℃, I would recommend the parameter values of $q''_{2\&3} < 467\ W/m^2$ and $\Delta x_s < 0.002755\ m$.

Appendix

In [2]:

```
#Task 1.1
import numpy as np

xdata = []
ydata = []
#xdata.append([ Di(m), qoflux (kW/m^2), mdot (kg/s)])


xdata.append([0.008, 550, 0.06157])
xdata.append([0.008, 650, 0.07269])
xdata.append([0.008, 750, 0.08396])
xdata.append([0.008, 850, 0.09347])
xdata.append([0.008, 950, 0.10635])
xdata.append([0.008, 1050, 0.11521])
xdata.append([0.008, 1150, 0.1287])
xdata.append([0.008, 850, 0.09516])
xdata.append([0.008, 550, 0.04398])
xdata.append([0.008, 750, 0.05997])
xdata.append([0.008, 950, 0.07596])
xdata.append([0.008, 1050, 0.08343])
xdata.append([0.008, 1150, 0.0919])
xdata.append([0.008, 850, 0.06797])
xdata.append([0.008, 550, 0.0342])
xdata.append([0.008, 750, 0.04664])
xdata.append([0.008, 950, 0.05908])
xdata.append([0.008, 1150, 0.0715])
xdata.append([0.008, 850, 0.05286])
xdata.append([0.011, 550, 0.0846])
xdata.append([0.011, 750, 0.1154])
xdata.append([0.011, 950, 0.1462])
xdata.append([0.011, 1150, 0.177])
xdata.append([0.011, 850, 0.1308])
xdata.append([0.011, 550, 0.06047])
xdata.append([0.011, 750, 0.08246])
xdata.append([0.011, 950, 0.1044])
xdata.append([0.011, 1050, 0.1134])
xdata.append([0.011, 1150, 0.1264])
xdata.append([0.011, 850, 0.0934])
xdata.append([0.011, 550, 0.047])
xdata.append([0.011, 750, 0.06413])
xdata.append([0.011, 950, 0.08124])
xdata.append([0.011, 1150, 0.09834])
xdata.append([0.011, 850, 0.072691])
xdata.append([0.011, 700, 0.087196])
xdata.append([0.013, 550, 0.10005])
xdata.append([0.013, 750, 0.13644])
xdata.append([0.013, 950, 0.17282])
xdata.append([0.013, 1150, 0.2092])
xdata.append([0.013, 850, 0.15463])
xdata.append([0.013, 550, 0.07147])
xdata.append([0.013, 750, 0.09745])
```

```
xdata.append([0.013, 950, 0.12344])
xdata.append([0.013, 1050, 0.13302])
xdata.append([0.013, 1150, 0.1494])
xdata.append([0.013, 850, 0.11045])
xdata.append([0.013, 550, 0.05558])
xdata.append([0.013, 750, 0.0758])
xdata.append([0.013, 950, 0.09601])
xdata.append([0.013, 1150, 0.1162])
xdata.append([0.013, 850, 0.0859])

#ydata.append([ exit quality, max wall temperature (deg C)])

ydata.append([0.525, 306.7])
ydata.append([0.525, 298.5])
ydata.append([0.525, 294.5])
ydata.append([0.525, 290.2])
ydata.append([0.524, 286.9])
ydata.append([0.524, 284.1])
ydata.append([0.525, 281.7])
ydata.append([0.524, 290.3])
ydata.append([0.734, 307.9])
ydata.append([0.735, 295.5])
ydata.append([0.735, 287.8])
ydata.append([0.735, 285.0])
ydata.append([0.735, 282.5])
ydata.append([0.734, 291.3])
ydata.append([ 0.945, 308.6])
ydata.append([0.945, 296.2])
ydata.append([0.945, 288.5])
ydata.append([0.945, 283.1])
ydata.append([0.945, 291.9])
ydata.append([ 0.525, 328.0])
ydata.append([0.525, 311.2])
ydata.append([0.525, 300.8])
ydata.append([0.525, 293.6])
ydata.append([0.525, 305.5])
ydata.append([0.735, 329.6])
ydata.append([0.735, 312.6])
ydata.append([0.735, 302.0])
ydata.append([0.735, 299.4])
ydata.append([0.735, 294.8])
ydata.append([0.735, 306.8])
ydata.append([ 0.945, 330.7])
ydata.append([0.945, 313.6])
ydata.append([0.944, 302.9])
ydata.append([0.945, 295.6])
ydata.append([0.944, 307.7])
ydata.append([0.734, 324.7])
ydata.append([0.525, 342.2])
ydata.append([0.524,  322.3])
ydata.append([0.524, 310.0])
ydata.append([0.525, 301.6])
ydata.append([0.524, 315.5])
```

```
ydata.append([0.734, 344.1])
ydata.append([0.735, 324.0])
ydata.append([0.735, 311.5])
ydata.append([0.735, 306.3])
ydata.append([0.735, 302.9])
ydata.append([0.734, 317.1])
ydata.append([0.945, 345.3])
ydata.append([0.944, 325.1])
ydata.append([0.944, 312.5])
ydata.append([0.945, 303.9])
ydata.append([0.945, 318.2])

xarray= np.array(xdata)
yarray= np.array(ydata)
```

In [3]:

```
#Task 1.1a
import keras
import pandas as pd
from keras.models import Sequential
import numpy as np
import keras.backend as kb
import tensorflow as tf
import statistics as s
#the follwoing 2 lines are only needed for Mac OS machines
import os
os.environ['KMP_DUPLICATE_LIB_OK']='True'


Di =[] #inputs
q0 =[]
mdot =[]
xe = [] #outputs
Tw = []
xarrayn = []
yarrayn = []

for x in range(len(xarray)):
    Di.append(xarray[x][0])
    q0.append(xarray[x][1])
    mdot.append(xarray[x][2])

for y in range(len(yarray)):
    xe.append(yarray[y][0])
    Tw.append(yarray[y][1])

def median(sample):         #function to calculate median
    n = len(sample)
    i = n//2
    if n%2:
        return sorted (sample [i])
    return sum(sorted(sample)[i-1:i+1])/2
```

```
medDi = median(Di)
medq0 = median(q0)
medmdot = median(mdot)
medxe = median(xe)
medTw = median(Tw)

Din = Di/medDi
q0n = q0/medq0
mdotn = mdot/medmdot
xen = xe/medxe
Twn = Tw/medTw
xarrayn = np.column_stack((Din, q0n, mdotn))
yarrayn = np.column_stack((xen, Twn))

print(xarrayn)
print(yarrayn)
```

```
Using TensorFlow backend.
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 [1.18181818 0.88235294 1.05180788]
 [1.18181818 1.11764706 1.33232596]
 [1.18181818 1.23529412 1.43572585]
 [1.18181818 1.35294118 1.61252024]
 [1.18181818 1.         1.19212089]
 [1.18181818 0.64705882 0.59989207]
 [1.18181818 0.88235294 0.81813276]
 [1.18181818 1.11764706 1.03626552]
 [1.18181818 1.35294118 1.25418241]
 [1.18181818 1.         0.92714517]]
[[0.71428571 1.00656383]
 [0.71428571 0.97965212]
 [0.71428571 0.96652445]
 [0.71428571 0.95241221]
 [0.71292517 0.94158188]
 [0.71292517 0.93239252]
 [0.71428571 0.92451592]
 [0.71292517 0.9527404 ]
 [0.99863946 1.01050213]
 [1.         0.96980637]
 [1.         0.94453561]
 [1.         0.93534624]
 [1.         0.92714145]
 [0.99863946 0.95602232]
 [1.28571429 1.01279947]
 [1.28571429 0.97210371]
 [1.28571429 0.94683295]
 [1.28571429 0.9291106 ]
 [1.28571429 0.95799147]
 [0.71428571 1.07646866]
 [0.71428571 1.02133246]
 [0.71428571 0.98720053]
 [0.71428571 0.96357073]
 [0.71428571 1.00262553]
 [1.         1.08171972]
 [1.         1.02592714]
 [1.         0.99113883]
 [1.         0.98260584]
 [1.         0.96750903]
 [1.         1.00689202]
 [1.28571429 1.08532983]
 [1.28571429 1.02920906]
 [1.28435374 0.99409255]
 [1.28571429 0.97013456]
 [1.28435374 1.00984575]
 [0.99863946 1.06563833]
 [0.71428571 1.12307187]
 [0.71292517 1.05776173]
 [0.71292517 1.01739416]
 [0.71428571 0.98982606]
 [0.71292517 1.0354447 ]
 [0.99863946 1.12930752]
```

```
 [1.         1.06334099]
 [1.         1.02231703]
 [1.         1.00525107]
 [1.         0.99409255]
 [0.99863946 1.04069577]
 [1.28571429 1.13324582]
 [1.28435374 1.0669511 ]
 [1.28435374 1.02559895]
 [1.28571429 0.99737447]
 [1.28571429 1.04430587]]
```

In [97]:

```
#Task 1.1b
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(xarrayn, yarrayn, test_si

print(X_train)
print(y_train)
print(X_test)
print(y_test)
```

```
[[0.72727273 1.35294118 1.38909876]
 [1.         1.         0.78457636]
 [0.72727273 1.11764706 1.14786832]
 [1.18181818 0.88235294 1.47263896]
 [1.         0.64705882 0.65267134]
 [1.18181818 1.23529412 1.43572585]
 [1.         1.35294118 1.06141392]
 [1.18181818 1.11764706 1.03626552]
 [0.72727273 0.88235294 0.50339989]
 [0.72727273 0.88235294 0.64727469]
 [0.72727273 1.11764706 0.63766865]
 [1.         0.64705882 0.50728548]
 [1.18181818 0.64705882 1.07987048]
 [1.         0.88235294 0.89001619]
 [0.72727273 1.23529412 0.9004857 ]
 [0.72727273 0.64705882 0.66454398]
 [1.18181818 1.         1.19212089]
 [1.         1.23529412 1.22396114]
 [1.         0.88235294 0.69217485]
 [1.18181818 1.35294118 2.25796006]
 [1.         1.         1.00809498]
 [1.18181818 1.35294118 1.61252024]
 [0.72727273 0.76470588 0.78456557]
 [1.         1.11764706 1.57798165]
 [0.72727273 0.88235294 0.90620615]
 [1.18181818 1.         1.66896924]
 [1.         0.82352941 0.9411333 ]
 [1.         1.         1.41176471]
 [1.18181818 0.88235294 0.81813276]
 [0.72727273 1.11764706 0.81985969]
 [1.         1.35294118 1.91041554]
 [0.72727273 1.         0.57053427]
 [1.18181818 1.         0.92714517]
 [1.         0.88235294 1.24554776]
```

```
 [0.72727273 1.         1.0270912 ]
 [1.18181818 0.88235294 1.05180788]
 [0.72727273 0.64705882 0.36913114]
 [1.         1.35294118 1.36427415]
 [1.18181818 1.11764706 1.86529951]]
[[0.71428571 0.92451592]
 [1.28435374 1.00984575]
 [0.71292517 0.94158188]
 [0.71292517 1.05776173]
 [1.         1.08171972]
 [1.         1.00525107]
 [1.28571429 0.97013456]
 [1.28435374 1.02559895]
 [1.28571429 0.97210371]
 [1.         0.96980637]
 [1.28571429 0.94683295]
 [1.28571429 1.08532983]
 [0.71428571 1.12307187]
 [1.         1.02592714]
 [1.         0.93534624]
 [0.71428571 1.00656383]
 [0.99863946 1.04069577]
 [1.         0.98260584]
 [1.28571429 1.02920906]
 [0.71428571 0.98982606]
 [1.         1.00689202]
 [1.         0.99409255]
 [0.71428571 0.97965212]
 [0.71428571 0.98720053]
 [0.71428571 0.96652445]
 [0.71292517 1.0354447 ]
 [0.99863946 1.06563833]
 [0.71428571 1.00262553]
 [1.28435374 1.0669511 ]
 [1.         0.94453561]
 [0.71428571 0.96357073]
 [1.28571429 0.95799147]
 [1.28571429 1.04430587]
 [0.71428571 1.02133246]
 [0.71292517 0.9527404 ]
 [1.         1.06334099]
 [1.28571429 1.01279947]
 [1.         0.96750903]
 [0.71292517 1.01739416]]
[[1.         0.64705882 0.91311387]
 [1.18181818 0.64705882 0.77139773]
 [1.18181818 0.64705882 0.59989207]
 [0.72727273 1.35294118 0.99190502]
 [1.18181818 1.11764706 1.33232596]
 [0.72727273 1.23529412 1.24349703]
 [0.72727273 1.35294118 0.77172153]
 [1.18181818 1.35294118 1.25418241]
 [0.72727273 1.         1.00885051]
 [1.         1.11764706 0.87684835]
 [0.72727273 1.         0.73362115]
 [0.72727273 0.64705882 0.47468969]
 [1.         1.11764706 1.12682137]]
```

```
[[0.71428571 1.07646866]
 [0.99863946 1.12930752]
 [1.28571429 1.13324582]
 [1.         0.92714145]
 [1.         1.02231703]
 [0.71292517 0.93239252]
 [1.28571429 0.9291106 ]
 [1.28571429 0.99737447]
 [0.71428571 0.95241221]
 [1.28435374 0.99409255]
 [0.99863946 0.95602232]
 [0.99863946 1.01050213]
 [1.         0.99113883]]
```

In [98]:

```
# define neural network model

from keras import backend as K
#initialize weights
initializer = keras.initializers.RandomUniform(minval= -0.2, maxval=0.5)

model = keras.Sequential([
    keras.layers.Dense(6, activation=K.elu, input_shape=[3],  kernel_initiali
    keras.layers.Dense(8, activation=K.elu,  kernel_initializer=initializer),
    keras.layers.Dense(16, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(8, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(2,  kernel_initializer=initializer)
  ])
```

In [102…

```
#from tf.keras import optimizers
rms = keras.optimizers.RMSprop(0.005)
model.compile(loss='mean_absolute_error',optimizer=rms)
```

In [103…

```
# Add an early stopping callback
es = keras.callbacks.EarlyStopping(
    monitor='loss',
    mode='min',
    patience = 80,
    restore_best_weights = True,
    verbose=1)
# Add a checkpoint where loss is minimum, and save that model
mc = keras.callbacks.ModelCheckpoint('best_model.SB', monitor='loss',
                     mode='min',  verbose=1, save_best_only=True)

historyData = model.fit(X_train,y_train,epochs=800,callbacks=[es])

loss_hist = historyData.history['loss']
#The above line will return a dictionary, access it's info like this:
best_epoch = np.argmin(historyData.history['loss']) + 1
print ('best epoch = ', best_epoch)
print('smallest loss =', np.min(loss_hist))

model.save('./best_model')
```

```
Epoch 1/800
39/39 [==============================] - 1s 29ms/step - loss: 0.0824
Epoch 2/800
39/39 [==============================] - 0s 241us/step - loss: 0.0512
Epoch 3/800
39/39 [==============================] - 0s 357us/step - loss: 0.0480
Epoch 4/800
39/39 [==============================] - 0s 567us/step - loss: 0.0488
Epoch 5/800
39/39 [==============================] - 0s 508us/step - loss: 0.0512
Epoch 6/800
39/39 [==============================] - 0s 558us/step - loss: 0.0525
Epoch 7/800
39/39 [==============================] - 0s 686us/step - loss: 0.0468
Epoch 8/800
39/39 [==============================] - 0s 482us/step - loss: 0.0490
Epoch 9/800
39/39 [==============================] - 0s 494us/step - loss: 0.0464
Epoch 10/800
39/39 [==============================] - 0s 588us/step - loss: 0.0475
Epoch 11/800
39/39 [==============================] - 0s 501us/step - loss: 0.0457
Epoch 12/800
39/39 [==============================] - 0s 661us/step - loss: 0.0486
Epoch 13/800
39/39 [==============================] - 0s 659us/step - loss: 0.0453
Epoch 14/800
39/39 [==============================] - 0s 556us/step - loss: 0.0471
Epoch 15/800
39/39 [==============================] - 0s 716us/step - loss: 0.0460
Epoch 16/800
39/39 [==============================] - 0s 388us/step - loss: 0.0478
Epoch 17/800
```

```
39/39 [==============================] - 0s 334us/step - loss: 0.0479
Epoch 18/800
39/39 [==============================] - 0s 274us/step - loss: 0.0476
Epoch 19/800
39/39 [==============================] - 0s 315us/step - loss: 0.0478
Epoch 20/800
39/39 [==============================] - 0s 304us/step - loss: 0.0442
Epoch 21/800
39/39 [==============================] - 0s 229us/step - loss: 0.0446
Epoch 22/800
39/39 [==============================] - 0s 357us/step - loss: 0.0450
Epoch 23/800
39/39 [==============================] - 0s 301us/step - loss: 0.0460
Epoch 24/800
39/39 [==============================] - 0s 476us/step - loss: 0.0435
Epoch 25/800
39/39 [==============================] - 0s 623us/step - loss: 0.0441
Epoch 26/800
39/39 [==============================] - 0s 380us/step - loss: 0.0547
Epoch 27/800
39/39 [==============================] - 0s 285us/step - loss: 0.0459
Epoch 28/800
39/39 [==============================] - 0s 371us/step - loss: 0.0442
Epoch 29/800
39/39 [==============================] - 0s 283us/step - loss: 0.0444
Epoch 30/800
39/39 [==============================] - 0s 264us/step - loss: 0.0467
Epoch 31/800
39/39 [==============================] - 0s 384us/step - loss: 0.0445
Epoch 32/800
39/39 [==============================] - 0s 575us/step - loss: 0.0478
Epoch 33/800
39/39 [==============================] - 0s 459us/step - loss: 0.0448
Epoch 34/800
39/39 [==============================] - 0s 673us/step - loss: 0.0446
Epoch 35/800
39/39 [==============================] - 0s 432us/step - loss: 0.0450
Epoch 36/800
39/39 [==============================] - 0s 359us/step - loss: 0.0450
Epoch 37/800
39/39 [==============================] - 0s 381us/step - loss: 0.0445
Epoch 38/800
39/39 [==============================] - 0s 516us/step - loss: 0.0467
Epoch 39/800
39/39 [==============================] - 0s 681us/step - loss: 0.0433
Epoch 40/800
39/39 [==============================] - 0s 676us/step - loss: 0.0475
Epoch 41/800
39/39 [==============================] - 0s 707us/step - loss: 0.0444
Epoch 42/800
39/39 [==============================] - 0s 542us/step - loss: 0.0432
Epoch 43/800
39/39 [==============================] - 0s 621us/step - loss: 0.0448
Epoch 44/800
39/39 [==============================] - 0s 696us/step - loss: 0.0426
Epoch 45/800
39/39 [==============================] - 0s 352us/step - loss: 0.0416
```

```
Epoch 46/800
39/39 [==============================] - 0s 684us/step - loss: 0.0447
Epoch 47/800
39/39 [==============================] - 0s 441us/step - loss: 0.0427
Epoch 48/800
39/39 [==============================] - 0s 415us/step - loss: 0.0432
Epoch 49/800
39/39 [==============================] - 0s 520us/step - loss: 0.0498
Epoch 50/800
39/39 [==============================] - 0s 430us/step - loss: 0.0442
Epoch 51/800
39/39 [==============================] - 0s 594us/step - loss: 0.0426
Epoch 52/800
39/39 [==============================] - 0s 766us/step - loss: 0.0456
Epoch 53/800
39/39 [==============================] - 0s 897us/step - loss: 0.0475
Epoch 54/800
39/39 [==============================] - 0s 846us/step - loss: 0.0421
Epoch 55/800
39/39 [==============================] - 0s 481us/step - loss: 0.0413
Epoch 56/800
39/39 [==============================] - 0s 605us/step - loss: 0.0408
Epoch 57/800
39/39 [==============================] - 0s 566us/step - loss: 0.0454
Epoch 58/800
39/39 [==============================] - 0s 485us/step - loss: 0.0429
Epoch 59/800
39/39 [==============================] - 0s 435us/step - loss: 0.0425
Epoch 60/800
39/39 [==============================] - 0s 446us/step - loss: 0.0450
Epoch 61/800
39/39 [==============================] - 0s 291us/step - loss: 0.0420
Epoch 62/800
39/39 [==============================] - 0s 487us/step - loss: 0.0435
Epoch 63/800
39/39 [==============================] - 0s 313us/step - loss: 0.0415
Epoch 64/800
39/39 [==============================] - 0s 400us/step - loss: 0.0488
Epoch 65/800
39/39 [==============================] - 0s 392us/step - loss: 0.0423
Epoch 66/800
39/39 [==============================] - 0s 250us/step - loss: 0.0428
Epoch 67/800
39/39 [==============================] - 0s 254us/step - loss: 0.0421
Epoch 68/800
39/39 [==============================] - 0s 267us/step - loss: 0.0399
Epoch 69/800
39/39 [==============================] - 0s 261us/step - loss: 0.0446
Epoch 70/800
39/39 [==============================] - 0s 324us/step - loss: 0.0439
Epoch 71/800
39/39 [==============================] - 0s 318us/step - loss: 0.0484
Epoch 72/800
39/39 [==============================] - 0s 328us/step - loss: 0.0393
Epoch 73/800
39/39 [==============================] - 0s 266us/step - loss: 0.0425
Epoch 74/800
```

```
39/39 [==============================] - 0s 311us/step - loss: 0.0413
Epoch 75/800
39/39 [==============================] - 0s 266us/step - loss: 0.0413
Epoch 76/800
39/39 [==============================] - 0s 251us/step - loss: 0.0412
Epoch 77/800
39/39 [==============================] - 0s 272us/step - loss: 0.0402
Epoch 78/800
39/39 [==============================] - 0s 251us/step - loss: 0.0409
Epoch 79/800
39/39 [==============================] - 0s 230us/step - loss: 0.0412
Epoch 80/800
39/39 [==============================] - 0s 311us/step - loss: 0.0383
Epoch 81/800
39/39 [==============================] - 0s 341us/step - loss: 0.0392
Epoch 82/800
39/39 [==============================] - 0s 246us/step - loss: 0.0437
Epoch 83/800
39/39 [==============================] - 0s 339us/step - loss: 0.0474
Epoch 84/800
39/39 [==============================] - 0s 241us/step - loss: 0.0391
Epoch 85/800
39/39 [==============================] - 0s 290us/step - loss: 0.0398
Epoch 86/800
39/39 [==============================] - 0s 307us/step - loss: 0.0392
Epoch 87/800
39/39 [==============================] - 0s 353us/step - loss: 0.0411
Epoch 88/800
39/39 [==============================] - 0s 267us/step - loss: 0.0455
Epoch 89/800
39/39 [==============================] - 0s 297us/step - loss: 0.0442
Epoch 90/800
39/39 [==============================] - 0s 305us/step - loss: 0.0400
Epoch 91/800
39/39 [==============================] - 0s 344us/step - loss: 0.0404
Epoch 92/800
39/39 [==============================] - 0s 394us/step - loss: 0.0414
Epoch 93/800
39/39 [==============================] - 0s 335us/step - loss: 0.0418
Epoch 94/800
39/39 [==============================] - 0s 349us/step - loss: 0.0431
Epoch 95/800
39/39 [==============================] - 0s 378us/step - loss: 0.0392
Epoch 96/800
39/39 [==============================] - 0s 383us/step - loss: 0.0407
Epoch 97/800
39/39 [==============================] - 0s 376us/step - loss: 0.0506
Epoch 98/800
39/39 [==============================] - 0s 450us/step - loss: 0.0379
Epoch 99/800
39/39 [==============================] - 0s 408us/step - loss: 0.0403
Epoch 100/800
39/39 [==============================] - 0s 570us/step - loss: 0.0381
Epoch 101/800
39/39 [==============================] - 0s 533us/step - loss: 0.0434
Epoch 102/800
39/39 [==============================] - 0s 450us/step - loss: 0.0451
```

```
Epoch 103/800
39/39 [==============================] - 0s 433us/step - loss: 0.0391
Epoch 104/800
39/39 [==============================] - 0s 377us/step - loss: 0.0392
Epoch 105/800
39/39 [==============================] - 0s 616us/step - loss: 0.0406
Epoch 106/800
39/39 [==============================] - 0s 334us/step - loss: 0.0455
Epoch 107/800
39/39 [==============================] - 0s 385us/step - loss: 0.0428
Epoch 108/800
39/39 [==============================] - 0s 322us/step - loss: 0.0407
Epoch 109/800
39/39 [==============================] - 0s 343us/step - loss: 0.0412
Epoch 110/800
39/39 [==============================] - 0s 447us/step - loss: 0.0449
Epoch 111/800
39/39 [==============================] - 0s 324us/step - loss: 0.0436
Epoch 112/800
39/39 [==============================] - 0s 401us/step - loss: 0.0373
Epoch 113/800
39/39 [==============================] - 0s 406us/step - loss: 0.0389
Epoch 114/800
39/39 [==============================] - 0s 430us/step - loss: 0.0467
Epoch 115/800
39/39 [==============================] - 0s 859us/step - loss: 0.0388
Epoch 116/800
39/39 [==============================] - 0s 506us/step - loss: 0.0370
Epoch 117/800
39/39 [==============================] - 0s 367us/step - loss: 0.0408
Epoch 118/800
39/39 [==============================] - 0s 466us/step - loss: 0.0445
Epoch 119/800
39/39 [==============================] - 0s 383us/step - loss: 0.0367
Epoch 120/800
39/39 [==============================] - 0s 490us/step - loss: 0.0391
Epoch 121/800
39/39 [==============================] - ETA: 0s - loss: 0.042 - 0s 416us/step
- loss: 0.0387
Epoch 122/800
39/39 [==============================] - 0s 408us/step - loss: 0.0397
Epoch 123/800
39/39 [==============================] - 0s 481us/step - loss: 0.0471
Epoch 124/800
39/39 [==============================] - 0s 385us/step - loss: 0.0368
Epoch 125/800
39/39 [==============================] - 0s 302us/step - loss: 0.0387
Epoch 126/800
39/39 [==============================] - 0s 306us/step - loss: 0.0416
Epoch 127/800
39/39 [==============================] - 0s 300us/step - loss: 0.0383
Epoch 128/800
39/39 [==============================] - 0s 331us/step - loss: 0.0398
Epoch 129/800
39/39 [==============================] - 0s 259us/step - loss: 0.0495
Epoch 130/800
39/39 [==============================] - 0s 277us/step - loss: 0.0385
```

```
Epoch 131/800
39/39 [==============================] - 0s 342us/step - loss: 0.0357
Epoch 132/800
39/39 [==============================] - 0s 299us/step - loss: 0.0375
Epoch 133/800
39/39 [==============================] - 0s 314us/step - loss: 0.0359
Epoch 134/800
39/39 [==============================] - 0s 376us/step - loss: 0.0355
Epoch 135/800
39/39 [==============================] - 0s 382us/step - loss: 0.0378
Epoch 136/800
39/39 [==============================] - 0s 394us/step - loss: 0.0384
Epoch 137/800
39/39 [==============================] - 0s 364us/step - loss: 0.0393
Epoch 138/800
39/39 [==============================] - 0s 398us/step - loss: 0.0443
Epoch 139/800
39/39 [==============================] - 0s 368us/step - loss: 0.0367
Epoch 140/800
39/39 [==============================] - 0s 432us/step - loss: 0.0309
Epoch 141/800
39/39 [==============================] - 0s 334us/step - loss: 0.0407
Epoch 142/800
39/39 [==============================] - 0s 363us/step - loss: 0.0319
Epoch 143/800
39/39 [==============================] - 0s 268us/step - loss: 0.0320
Epoch 144/800
39/39 [==============================] - 0s 526us/step - loss: 0.0432
Epoch 145/800
39/39 [==============================] - 0s 706us/step - loss: 0.0331
Epoch 146/800
39/39 [==============================] - 0s 590us/step - loss: 0.0317
Epoch 147/800
39/39 [==============================] - 0s 737us/step - loss: 0.0305
Epoch 148/800
39/39 [==============================] - 0s 756us/step - loss: 0.0428
Epoch 149/800
39/39 [==============================] - 0s 598us/step - loss: 0.0339
Epoch 150/800
39/39 [==============================] - 0s 762us/step - loss: 0.0338
Epoch 151/800
39/39 [==============================] - 0s 462us/step - loss: 0.0339
Epoch 152/800
39/39 [==============================] - 0s 531us/step - loss: 0.0446
Epoch 153/800
39/39 [==============================] - 0s 386us/step - loss: 0.0371
Epoch 154/800
39/39 [==============================] - 0s 442us/step - loss: 0.0365
Epoch 155/800
39/39 [==============================] - 0s 362us/step - loss: 0.0287
Epoch 156/800
39/39 [==============================] - 0s 367us/step - loss: 0.0361
Epoch 157/800
39/39 [==============================] - 0s 329us/step - loss: 0.0287
Epoch 158/800
39/39 [==============================] - 0s 393us/step - loss: 0.0519
Epoch 159/800
```

```
39/39 [==============================] - 0s 266us/step - loss: 0.0332
Epoch 160/800
39/39 [==============================] - 0s 298us/step - loss: 0.0349
Epoch 161/800
39/39 [==============================] - 0s 267us/step - loss: 0.0285
Epoch 162/800
39/39 [==============================] - 0s 570us/step - loss: 0.0294
Epoch 163/800
39/39 [==============================] - 0s 367us/step - loss: 0.0293
Epoch 164/800
39/39 [==============================] - 0s 338us/step - loss: 0.0333
Epoch 165/800
39/39 [==============================] - 0s 333us/step - loss: 0.0400
Epoch 166/800
39/39 [==============================] - 0s 309us/step - loss: 0.0349
Epoch 167/800
39/39 [==============================] - 0s 254us/step - loss: 0.0300
Epoch 168/800
39/39 [==============================] - 0s 375us/step - loss: 0.0483
Epoch 169/800
39/39 [==============================] - 0s 351us/step - loss: 0.0314
Epoch 170/800
39/39 [==============================] - 0s 442us/step - loss: 0.0248
Epoch 171/800
39/39 [==============================] - 0s 509us/step - loss: 0.0296
Epoch 172/800
39/39 [==============================] - 0s 630us/step - loss: 0.0353
Epoch 173/800
39/39 [==============================] - 0s 659us/step - loss: 0.0314
Epoch 174/800
39/39 [==============================] - 0s 574us/step - loss: 0.0325
Epoch 175/800
39/39 [==============================] - 0s 485us/step - loss: 0.0389
Epoch 176/800
39/39 [==============================] - 0s 498us/step - loss: 0.0326
Epoch 177/800
39/39 [==============================] - 0s 652us/step - loss: 0.0373
Epoch 178/800
39/39 [==============================] - 0s 500us/step - loss: 0.0310
Epoch 179/800
39/39 [==============================] - 0s 442us/step - loss: 0.0360
Epoch 180/800
39/39 [==============================] - 0s 335us/step - loss: 0.0336
Epoch 181/800
39/39 [==============================] - 0s 316us/step - loss: 0.0294
Epoch 182/800
39/39 [==============================] - 0s 329us/step - loss: 0.0297
Epoch 183/800
39/39 [==============================] - 0s 385us/step - loss: 0.0260
Epoch 184/800
39/39 [==============================] - 0s 305us/step - loss: 0.0347
Epoch 185/800
39/39 [==============================] - 0s 267us/step - loss: 0.0267
Epoch 186/800
39/39 [==============================] - 0s 307us/step - loss: 0.0299
Epoch 187/800
39/39 [==============================] - 0s 356us/step - loss: 0.0269
```

```
Epoch 188/800
39/39 [==============================] - 0s 337us/step - loss: 0.0326
Epoch 189/800
39/39 [==============================] - 0s 360us/step - loss: 0.0263
Epoch 190/800
39/39 [==============================] - 0s 398us/step - loss: 0.0294
Epoch 191/800
39/39 [==============================] - 0s 549us/step - loss: 0.0435
Epoch 192/800
39/39 [==============================] - 0s 473us/step - loss: 0.0280
Epoch 193/800
39/39 [==============================] - 0s 363us/step - loss: 0.0240
Epoch 194/800
39/39 [==============================] - 0s 323us/step - loss: 0.0268
Epoch 195/800
39/39 [==============================] - 0s 369us/step - loss: 0.0302
Epoch 196/800
39/39 [==============================] - 0s 424us/step - loss: 0.0268
Epoch 197/800
39/39 [==============================] - 0s 344us/step - loss: 0.0313
Epoch 198/800
39/39 [==============================] - 0s 329us/step - loss: 0.0332
Epoch 199/800
39/39 [==============================] - 0s 364us/step - loss: 0.0291
Epoch 200/800
39/39 [==============================] - 0s 383us/step - loss: 0.0276
Epoch 201/800
39/39 [==============================] - 0s 443us/step - loss: 0.0236
Epoch 202/800
39/39 [==============================] - 0s 280us/step - loss: 0.0320
Epoch 203/800
39/39 [==============================] - 0s 341us/step - loss: 0.0345
Epoch 204/800
39/39 [==============================] - 0s 423us/step - loss: 0.0284
Epoch 205/800
39/39 [==============================] - 0s 329us/step - loss: 0.0281
Epoch 206/800
39/39 [==============================] - 0s 334us/step - loss: 0.0380
Epoch 207/800
39/39 [==============================] - 0s 364us/step - loss: 0.0261
Epoch 208/800
39/39 [==============================] - 0s 285us/step - loss: 0.0350
Epoch 209/800
39/39 [==============================] - 0s 358us/step - loss: 0.0250
Epoch 210/800
39/39 [==============================] - 0s 335us/step - loss: 0.0293
Epoch 211/800
39/39 [==============================] - 0s 310us/step - loss: 0.0294
Epoch 212/800
39/39 [==============================] - 0s 359us/step - loss: 0.0337
Epoch 213/800
39/39 [==============================] - 0s 458us/step - loss: 0.0240
Epoch 214/800
39/39 [==============================] - 0s 487us/step - loss: 0.0336
Epoch 215/800
39/39 [==============================] - 0s 376us/step - loss: 0.0282
Epoch 216/800
```

```
39/39 [==============================] - 0s 429us/step - loss: 0.0299
Epoch 217/800
39/39 [==============================] - 0s 391us/step - loss: 0.0290
Epoch 218/800
39/39 [==============================] - 0s 446us/step - loss: 0.0318
Epoch 219/800
39/39 [==============================] - 0s 538us/step - loss: 0.0222
Epoch 220/800
39/39 [==============================] - 0s 478us/step - loss: 0.0324
Epoch 221/800
39/39 [==============================] - 0s 393us/step - loss: 0.0241
Epoch 222/800
39/39 [==============================] - 0s 256us/step - loss: 0.0419
Epoch 223/800
39/39 [==============================] - 0s 268us/step - loss: 0.0264
Epoch 224/800
39/39 [==============================] - 0s 343us/step - loss: 0.0282
Epoch 225/800
39/39 [==============================] - 0s 259us/step - loss: 0.0345
Epoch 226/800
39/39 [==============================] - 0s 296us/step - loss: 0.0288
Epoch 227/800
39/39 [==============================] - 0s 263us/step - loss: 0.0240
Epoch 228/800
39/39 [==============================] - 0s 294us/step - loss: 0.0273
Epoch 229/800
39/39 [==============================] - 0s 305us/step - loss: 0.0225
Epoch 230/800
39/39 [==============================] - 0s 440us/step - loss: 0.0243
Epoch 231/800
39/39 [==============================] - 0s 389us/step - loss: 0.0310
Epoch 232/800
39/39 [==============================] - 0s 314us/step - loss: 0.0304
Epoch 233/800
39/39 [==============================] - 0s 317us/step - loss: 0.0272
Epoch 234/800
39/39 [==============================] - 0s 333us/step - loss: 0.0248
Epoch 235/800
39/39 [==============================] - 0s 326us/step - loss: 0.0286
Epoch 236/800
39/39 [==============================] - 0s 436us/step - loss: 0.0285
Epoch 237/800
39/39 [==============================] - 0s 318us/step - loss: 0.0257
Epoch 238/800
39/39 [==============================] - 0s 402us/step - loss: 0.0309
Epoch 239/800
39/39 [==============================] - 0s 457us/step - loss: 0.0297
Epoch 240/800
39/39 [==============================] - 0s 391us/step - loss: 0.0312
Epoch 241/800
39/39 [==============================] - 0s 369us/step - loss: 0.0356
Epoch 242/800
39/39 [==============================] - 0s 323us/step - loss: 0.0284
Epoch 243/800
39/39 [==============================] - 0s 372us/step - loss: 0.0299
Epoch 244/800
39/39 [==============================] - 0s 429us/step - loss: 0.0277
```

```
Epoch 245/800
39/39 [==============================] - 0s 413us/step - loss: 0.0263
Epoch 246/800
39/39 [==============================] - 0s 355us/step - loss: 0.0272
Epoch 247/800
39/39 [==============================] - 0s 389us/step - loss: 0.0270
Epoch 248/800
39/39 [==============================] - 0s 372us/step - loss: 0.0297
Epoch 249/800
39/39 [==============================] - 0s 371us/step - loss: 0.0270
Epoch 250/800
39/39 [==============================] - 0s 348us/step - loss: 0.0317
Epoch 251/800
39/39 [==============================] - 0s 337us/step - loss: 0.0313
Epoch 252/800
39/39 [==============================] - 0s 414us/step - loss: 0.0295
Epoch 253/800
39/39 [==============================] - 0s 379us/step - loss: 0.0242
Epoch 254/800
39/39 [==============================] - 0s 435us/step - loss: 0.0236
Epoch 255/800
39/39 [==============================] - 0s 427us/step - loss: 0.0302
Epoch 256/800
39/39 [==============================] - 0s 400us/step - loss: 0.0290
Epoch 257/800
39/39 [==============================] - 0s 311us/step - loss: 0.0298
Epoch 258/800
39/39 [==============================] - 0s 393us/step - loss: 0.0311
Epoch 259/800
39/39 [==============================] - 0s 391us/step - loss: 0.0285
Epoch 260/800
39/39 [==============================] - 0s 364us/step - loss: 0.0270
Epoch 261/800
39/39 [==============================] - 0s 403us/step - loss: 0.0245
Epoch 262/800
39/39 [==============================] - 0s 378us/step - loss: 0.0329
Epoch 263/800
39/39 [==============================] - 0s 316us/step - loss: 0.0312
Epoch 264/800
39/39 [==============================] - 0s 376us/step - loss: 0.0290
Epoch 265/800
39/39 [==============================] - 0s 302us/step - loss: 0.0282
Epoch 266/800
39/39 [==============================] - 0s 310us/step - loss: 0.0221
Epoch 267/800
39/39 [==============================] - 0s 306us/step - loss: 0.0207
Epoch 268/800
39/39 [==============================] - 0s 292us/step - loss: 0.0236
Epoch 269/800
39/39 [==============================] - 0s 445us/step - loss: 0.0261
Epoch 270/800
39/39 [==============================] - 0s 393us/step - loss: 0.0309
Epoch 271/800
39/39 [==============================] - 0s 489us/step - loss: 0.0277
Epoch 272/800
39/39 [==============================] - 0s 326us/step - loss: 0.0259
Epoch 273/800
```

```
39/39 [==============================] - 0s 327us/step - loss: 0.0265
Epoch 274/800
39/39 [==============================] - 0s 344us/step - loss: 0.0275
Epoch 275/800
39/39 [==============================] - 0s 355us/step - loss: 0.0303
Epoch 276/800
39/39 [==============================] - 0s 365us/step - loss: 0.0275
Epoch 277/800
39/39 [==============================] - 0s 353us/step - loss: 0.0219
Epoch 278/800
39/39 [==============================] - 0s 406us/step - loss: 0.0235
Epoch 279/800
39/39 [==============================] - 0s 366us/step - loss: 0.0291
Epoch 280/800
39/39 [==============================] - 0s 541us/step - loss: 0.0287
Epoch 281/800
39/39 [==============================] - 0s 795us/step - loss: 0.0348
Epoch 282/800
39/39 [==============================] - 0s 629us/step - loss: 0.0219
Epoch 283/800
39/39 [==============================] - 0s 492us/step - loss: 0.0222
Epoch 284/800
39/39 [==============================] - 0s 390us/step - loss: 0.0210
Epoch 285/800
39/39 [==============================] - 0s 385us/step - loss: 0.0300
Epoch 286/800
39/39 [==============================] - 0s 490us/step - loss: 0.0331
Epoch 287/800
39/39 [==============================] - 0s 334us/step - loss: 0.0243
Epoch 288/800
39/39 [==============================] - 0s 305us/step - loss: 0.0326
Epoch 289/800
39/39 [==============================] - 0s 421us/step - loss: 0.0329
Epoch 290/800
39/39 [==============================] - 0s 410us/step - loss: 0.0313
Epoch 291/800
39/39 [==============================] - 0s 725us/step - loss: 0.0253
Epoch 292/800
39/39 [==============================] - 0s 417us/step - loss: 0.0298
Epoch 293/800
39/39 [==============================] - 0s 368us/step - loss: 0.0230
Epoch 294/800
39/39 [==============================] - 0s 360us/step - loss: 0.0254
Epoch 295/800
39/39 [==============================] - 0s 294us/step - loss: 0.0268
Epoch 296/800
39/39 [==============================] - 0s 448us/step - loss: 0.0271
Epoch 297/800
39/39 [==============================] - 0s 475us/step - loss: 0.0364
Epoch 298/800
39/39 [==============================] - 0s 389us/step - loss: 0.0247
Epoch 299/800
39/39 [==============================] - 0s 391us/step - loss: 0.0223
Epoch 300/800
39/39 [==============================] - ETA: 0s - loss: 0.024 - 0s 388us/step
- loss: 0.0260
Epoch 301/800
```

```
39/39 [==============================] - 0s 376us/step - loss: 0.0246
Epoch 302/800
39/39 [==============================] - 0s 341us/step - loss: 0.0228
Epoch 303/800
39/39 [==============================] - 0s 352us/step - loss: 0.0279
Epoch 304/800
39/39 [==============================] - 0s 443us/step - loss: 0.0265
Epoch 305/800
39/39 [==============================] - 0s 396us/step - loss: 0.0275
Epoch 306/800
39/39 [==============================] - 0s 377us/step - loss: 0.0295
Epoch 307/800
39/39 [==============================] - 0s 394us/step - loss: 0.0349
Epoch 308/800
39/39 [==============================] - 0s 424us/step - loss: 0.0233
Epoch 309/800
39/39 [==============================] - 0s 326us/step - loss: 0.0240
Epoch 310/800
39/39 [==============================] - 0s 357us/step - loss: 0.0281
Epoch 311/800
39/39 [==============================] - 0s 376us/step - loss: 0.0252
Epoch 312/800
39/39 [==============================] - 0s 376us/step - loss: 0.0269
Epoch 313/800
39/39 [==============================] - 0s 363us/step - loss: 0.0279
Epoch 314/800
39/39 [==============================] - 0s 330us/step - loss: 0.0246
Epoch 315/800
39/39 [==============================] - 0s 435us/step - loss: 0.0329
Epoch 316/800
39/39 [==============================] - 0s 340us/step - loss: 0.0275
Epoch 317/800
39/39 [==============================] - 0s 290us/step - loss: 0.0248
Epoch 318/800
39/39 [==============================] - 0s 349us/step - loss: 0.0246
Epoch 319/800
39/39 [==============================] - 0s 433us/step - loss: 0.0235
Epoch 320/800
39/39 [==============================] - 0s 477us/step - loss: 0.0265
Epoch 321/800
39/39 [==============================] - 0s 404us/step - loss: 0.0239
Epoch 322/800
39/39 [==============================] - 0s 397us/step - loss: 0.0363
Epoch 323/800
39/39 [==============================] - 0s 435us/step - loss: 0.0266
Epoch 324/800
39/39 [==============================] - 0s 406us/step - loss: 0.0196
Epoch 325/800
39/39 [==============================] - 0s 293us/step - loss: 0.0255
Epoch 326/800
39/39 [==============================] - 0s 736us/step - loss: 0.0282
Epoch 327/800
39/39 [==============================] - 0s 653us/step - loss: 0.0277
Epoch 328/800
39/39 [==============================] - 0s 712us/step - loss: 0.0264
Epoch 329/800
39/39 [==============================] - 0s 573us/step - loss: 0.0204
```

```
Epoch 330/800
39/39 [==============================] - 0s 534us/step - loss: 0.0235
Epoch 331/800
39/39 [==============================] - 0s 469us/step - loss: 0.0236
Epoch 332/800
39/39 [==============================] - 0s 589us/step - loss: 0.0291
Epoch 333/800
39/39 [==============================] - 0s 317us/step - loss: 0.0269
Epoch 334/800
39/39 [==============================] - 0s 398us/step - loss: 0.0262
Epoch 335/800
39/39 [==============================] - 0s 518us/step - loss: 0.0239
Epoch 336/800
39/39 [==============================] - 0s 554us/step - loss: 0.0278
Epoch 337/800
39/39 [==============================] - 0s 400us/step - loss: 0.0251
Epoch 338/800
39/39 [==============================] - 0s 286us/step - loss: 0.0253
Epoch 339/800
39/39 [==============================] - 0s 318us/step - loss: 0.0265
Epoch 340/800
39/39 [==============================] - 0s 336us/step - loss: 0.0214
Epoch 341/800
39/39 [==============================] - 0s 320us/step - loss: 0.0216
Epoch 342/800
39/39 [==============================] - 0s 336us/step - loss: 0.0279
Epoch 343/800
39/39 [==============================] - 0s 573us/step - loss: 0.0308
Epoch 344/800
39/39 [==============================] - 0s 406us/step - loss: 0.0236
Epoch 345/800
39/39 [==============================] - 0s 292us/step - loss: 0.0283
Epoch 346/800
39/39 [==============================] - 0s 309us/step - loss: 0.0258
Epoch 347/800
39/39 [==============================] - 0s 381us/step - loss: 0.0386
Epoch 348/800
39/39 [==============================] - 0s 384us/step - loss: 0.0205
Epoch 349/800
39/39 [==============================] - 0s 389us/step - loss: 0.0233
Epoch 350/800
39/39 [==============================] - 0s 357us/step - loss: 0.0277
Epoch 351/800
39/39 [==============================] - 0s 385us/step - loss: 0.0205
Epoch 352/800
39/39 [==============================] - 0s 401us/step - loss: 0.0259
Epoch 353/800
39/39 [==============================] - 0s 555us/step - loss: 0.0252
Epoch 354/800
39/39 [==============================] - 0s 438us/step - loss: 0.0231
Epoch 355/800
39/39 [==============================] - 0s 385us/step - loss: 0.0243
Epoch 356/800
39/39 [==============================] - 0s 353us/step - loss: 0.0305
Epoch 357/800
39/39 [==============================] - 0s 362us/step - loss: 0.0235
Epoch 358/800
```

```
39/39 [==============================] - 0s 334us/step - loss: 0.0223
Epoch 359/800
39/39 [==============================] - 0s 366us/step - loss: 0.0292
Epoch 360/800
39/39 [==============================] - 0s 351us/step - loss: 0.0246
Epoch 361/800
39/39 [==============================] - 0s 367us/step - loss: 0.0198
Epoch 362/800
39/39 [==============================] - 0s 339us/step - loss: 0.0218
Epoch 363/800
39/39 [==============================] - 0s 245us/step - loss: 0.0290
Epoch 364/800
39/39 [==============================] - 0s 559us/step - loss: 0.0256
Epoch 365/800
39/39 [==============================] - 0s 753us/step - loss: 0.0270
Epoch 366/800
39/39 [==============================] - 0s 369us/step - loss: 0.0218
Epoch 367/800
39/39 [==============================] - 0s 269us/step - loss: 0.0204
Epoch 368/800
39/39 [==============================] - 0s 335us/step - loss: 0.0311
Epoch 369/800
39/39 [==============================] - 0s 387us/step - loss: 0.0198
Epoch 370/800
39/39 [==============================] - 0s 289us/step - loss: 0.0343
Epoch 371/800
39/39 [==============================] - 0s 597us/step - loss: 0.0246
Epoch 372/800
39/39 [==============================] - 0s 547us/step - loss: 0.0273
Epoch 373/800
39/39 [==============================] - 0s 726us/step - loss: 0.0338
Epoch 374/800
39/39 [==============================] - 0s 778us/step - loss: 0.0233
Epoch 375/800
39/39 [==============================] - 0s 799us/step - loss: 0.0243
Epoch 376/800
39/39 [==============================] - 0s 823us/step - loss: 0.0262
Epoch 377/800
39/39 [==============================] - 0s 664us/step - loss: 0.0195
Epoch 378/800
39/39 [==============================] - 0s 319us/step - loss: 0.0246
Epoch 379/800
39/39 [==============================] - 0s 252us/step - loss: 0.0238
Epoch 380/800
39/39 [==============================] - 0s 690us/step - loss: 0.0290
Epoch 381/800
39/39 [==============================] - 0s 679us/step - loss: 0.0187
Epoch 382/800
39/39 [==============================] - 0s 759us/step - loss: 0.0223
Epoch 383/800
39/39 [==============================] - 0s 685us/step - loss: 0.0262
Epoch 384/800
39/39 [==============================] - 0s 478us/step - loss: 0.0224
Epoch 385/800
39/39 [==============================] - 0s 383us/step - loss: 0.0221
Epoch 386/800
39/39 [==============================] - 0s 315us/step - loss: 0.0274
```

```
Epoch 387/800
39/39 [==============================] - 0s 296us/step - loss: 0.0315
Epoch 388/800
39/39 [==============================] - 0s 298us/step - loss: 0.0280
Epoch 389/800
39/39 [==============================] - 0s 361us/step - loss: 0.0231
Epoch 390/800
39/39 [==============================] - 0s 316us/step - loss: 0.0285
Epoch 391/800
39/39 [==============================] - 0s 260us/step - loss: 0.0240
Epoch 392/800
39/39 [==============================] - 0s 318us/step - loss: 0.0295
Epoch 393/800
39/39 [==============================] - 0s 287us/step - loss: 0.0195
Epoch 394/800
39/39 [==============================] - 0s 302us/step - loss: 0.0192
Epoch 395/800
39/39 [==============================] - 0s 365us/step - loss: 0.0211
Epoch 396/800
39/39 [==============================] - 0s 333us/step - loss: 0.0332
Epoch 397/800
39/39 [==============================] - 0s 370us/step - loss: 0.0192
Epoch 398/800
39/39 [==============================] - 0s 464us/step - loss: 0.0223
Epoch 399/800
39/39 [==============================] - 0s 511us/step - loss: 0.0255
Epoch 400/800
39/39 [==============================] - 0s 424us/step - loss: 0.0199
Epoch 401/800
39/39 [==============================] - 0s 527us/step - loss: 0.0221
Epoch 402/800
39/39 [==============================] - 0s 342us/step - loss: 0.0204
Epoch 403/800
39/39 [==============================] - 0s 377us/step - loss: 0.0208
Epoch 404/800
39/39 [==============================] - 0s 402us/step - loss: 0.0286
Epoch 405/800
39/39 [==============================] - 0s 363us/step - loss: 0.0240
Epoch 406/800
39/39 [==============================] - 0s 480us/step - loss: 0.0236
Epoch 407/800
39/39 [==============================] - 0s 696us/step - loss: 0.0207
Epoch 408/800
39/39 [==============================] - 0s 829us/step - loss: 0.0286
Epoch 409/800
39/39 [==============================] - 0s 790us/step - loss: 0.0241
Epoch 410/800
39/39 [==============================] - 0s 601us/step - loss: 0.0221
Epoch 411/800
39/39 [==============================] - 0s 386us/step - loss: 0.0204
Epoch 412/800
39/39 [==============================] - 0s 348us/step - loss: 0.0172
Epoch 413/800
39/39 [==============================] - 0s 410us/step - loss: 0.0185
Epoch 414/800
39/39 [==============================] - 0s 334us/step - loss: 0.0229
Epoch 415/800
```

```
39/39 [==============================] - 0s 269us/step - loss: 0.0249
Epoch 416/800
39/39 [==============================] - 0s 291us/step - loss: 0.0281
Epoch 417/800
39/39 [==============================] - 0s 362us/step - loss: 0.0285
Epoch 418/800
39/39 [==============================] - 0s 553us/step - loss: 0.0225
Epoch 419/800
39/39 [==============================] - 0s 696us/step - loss: 0.0212
Epoch 420/800
39/39 [==============================] - 0s 719us/step - loss: 0.0216
Epoch 421/800
39/39 [==============================] - 0s 761us/step - loss: 0.0212
Epoch 422/800
39/39 [==============================] - 0s 546us/step - loss: 0.0263
Epoch 423/800
39/39 [==============================] - 0s 745us/step - loss: 0.0200
Epoch 424/800
39/39 [==============================] - 0s 650us/step - loss: 0.0242
Epoch 425/800
39/39 [==============================] - 0s 808us/step - loss: 0.0227
Epoch 426/800
39/39 [==============================] - 0s 749us/step - loss: 0.0250
Epoch 427/800
39/39 [==============================] - 0s 907us/step - loss: 0.0185
Epoch 428/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0198
Epoch 429/800
39/39 [==============================] - 0s 676us/step - loss: 0.0335
Epoch 430/800
39/39 [==============================] - 0s 620us/step - loss: 0.0229
Epoch 431/800
39/39 [==============================] - 0s 464us/step - loss: 0.0210
Epoch 432/800
39/39 [==============================] - 0s 350us/step - loss: 0.0276
Epoch 433/800
39/39 [==============================] - 0s 333us/step - loss: 0.0261
Epoch 434/800
39/39 [==============================] - 0s 353us/step - loss: 0.0246
Epoch 435/800
39/39 [==============================] - 0s 362us/step - loss: 0.0223
Epoch 436/800
39/39 [==============================] - 0s 760us/step - loss: 0.0210
Epoch 437/800
39/39 [==============================] - 0s 371us/step - loss: 0.0221
Epoch 438/800
39/39 [==============================] - 0s 349us/step - loss: 0.0204
Epoch 439/800
39/39 [==============================] - 0s 411us/step - loss: 0.0221
Epoch 440/800
39/39 [==============================] - 0s 309us/step - loss: 0.0268
Epoch 441/800
39/39 [==============================] - 0s 384us/step - loss: 0.0197
Epoch 442/800
39/39 [==============================] - 0s 311us/step - loss: 0.0208
Epoch 443/800
39/39 [==============================] - 0s 619us/step - loss: 0.0178
```

```
Epoch 444/800
39/39 [==============================] - 0s 342us/step - loss: 0.0217
Epoch 445/800
39/39 [==============================] - 0s 338us/step - loss: 0.0226
Epoch 446/800
39/39 [==============================] - 0s 402us/step - loss: 0.0190
Epoch 447/800
39/39 [==============================] - 0s 370us/step - loss: 0.0222
Epoch 448/800
39/39 [==============================] - 0s 260us/step - loss: 0.0267
Epoch 449/800
39/39 [==============================] - 0s 285us/step - loss: 0.0237
Epoch 450/800
39/39 [==============================] - 0s 368us/step - loss: 0.0292
Epoch 451/800
39/39 [==============================] - 0s 930us/step - loss: 0.0258
Epoch 452/800
39/39 [==============================] - 0s 712us/step - loss: 0.0182
Epoch 453/800
39/39 [==============================] - 0s 837us/step - loss: 0.0229
Epoch 454/800
39/39 [==============================] - 0s 433us/step - loss: 0.0209
Epoch 455/800
39/39 [==============================] - 0s 378us/step - loss: 0.0170
Epoch 456/800
39/39 [==============================] - 0s 394us/step - loss: 0.0177
Epoch 457/800
39/39 [==============================] - 0s 336us/step - loss: 0.0248
Epoch 458/800
39/39 [==============================] - 0s 297us/step - loss: 0.0207
Epoch 459/800
39/39 [==============================] - 0s 316us/step - loss: 0.0245
Epoch 460/800
39/39 [==============================] - 0s 350us/step - loss: 0.0242
Epoch 461/800
39/39 [==============================] - 0s 281us/step - loss: 0.0223
Epoch 462/800
39/39 [==============================] - 0s 291us/step - loss: 0.0284
Epoch 463/800
39/39 [==============================] - 0s 331us/step - loss: 0.0193
Epoch 464/800
39/39 [==============================] - 0s 346us/step - loss: 0.0184
Epoch 465/800
39/39 [==============================] - 0s 349us/step - loss: 0.0250
Epoch 466/800
39/39 [==============================] - 0s 297us/step - loss: 0.0244
Epoch 467/800
39/39 [==============================] - 0s 320us/step - loss: 0.0155
Epoch 468/800
39/39 [==============================] - 0s 336us/step - loss: 0.0238
Epoch 469/800
39/39 [==============================] - 0s 363us/step - loss: 0.0200
Epoch 470/800
39/39 [==============================] - 0s 325us/step - loss: 0.0173
Epoch 471/800
39/39 [==============================] - 0s 369us/step - loss: 0.0245
Epoch 472/800
```

```
39/39 [==============================] - 0s 350us/step - loss: 0.0205
Epoch 473/800
39/39 [==============================] - 0s 421us/step - loss: 0.0191
Epoch 474/800
39/39 [==============================] - 0s 376us/step - loss: 0.0237
Epoch 475/800
39/39 [==============================] - 0s 284us/step - loss: 0.0335
Epoch 476/800
39/39 [==============================] - 0s 320us/step - loss: 0.0196
Epoch 477/800
39/39 [==============================] - 0s 277us/step - loss: 0.0270
Epoch 478/800
39/39 [==============================] - 0s 584us/step - loss: 0.0244
Epoch 479/800
39/39 [==============================] - 0s 782us/step - loss: 0.0232
Epoch 480/800
39/39 [==============================] - 0s 804us/step - loss: 0.0216
Epoch 481/800
39/39 [==============================] - 0s 733us/step - loss: 0.0186
Epoch 482/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0224
Epoch 483/800
39/39 [==============================] - 0s 457us/step - loss: 0.0221
Epoch 484/800
39/39 [==============================] - 0s 309us/step - loss: 0.0270
Epoch 485/800
39/39 [==============================] - 0s 386us/step - loss: 0.0181
Epoch 486/800
39/39 [==============================] - 0s 367us/step - loss: 0.0191
Epoch 487/800
39/39 [==============================] - 0s 355us/step - loss: 0.0192
Epoch 488/800
39/39 [==============================] - 0s 393us/step - loss: 0.0203
Epoch 489/800
39/39 [==============================] - 0s 372us/step - loss: 0.0212
Epoch 490/800
39/39 [==============================] - 0s 334us/step - loss: 0.0191
Epoch 491/800
39/39 [==============================] - 0s 327us/step - loss: 0.0212
Epoch 492/800
39/39 [==============================] - ETA: 0s - loss: 0.030 - 0s 260us/step
- loss: 0.0291
Epoch 493/800
39/39 [==============================] - 0s 315us/step - loss: 0.0212
Epoch 494/800
39/39 [==============================] - 0s 323us/step - loss: 0.0194
Epoch 495/800
39/39 [==============================] - 0s 372us/step - loss: 0.0198
Epoch 496/800
39/39 [==============================] - 0s 508us/step - loss: 0.0294
Epoch 497/800
39/39 [==============================] - 0s 634us/step - loss: 0.0155
Epoch 498/800
39/39 [==============================] - 0s 826us/step - loss: 0.0178
Epoch 499/800
39/39 [==============================] - 0s 539us/step - loss: 0.0293
Epoch 500/800
```

```
39/39 [==============================] - 0s 589us/step - loss: 0.0148
Epoch 501/800
39/39 [==============================] - 0s 850us/step - loss: 0.0264
Epoch 502/800
39/39 [==============================] - 0s 817us/step - loss: 0.0146
Epoch 503/800
39/39 [==============================] - 0s 870us/step - loss: 0.0205
Epoch 504/800
39/39 [==============================] - 0s 732us/step - loss: 0.0223
Epoch 505/800
39/39 [==============================] - 0s 693us/step - loss: 0.0208
Epoch 506/800
39/39 [==============================] - 0s 762us/step - loss: 0.0196
Epoch 507/800
39/39 [==============================] - 0s 731us/step - loss: 0.0185
Epoch 508/800
39/39 [==============================] - 0s 726us/step - loss: 0.0183
Epoch 509/800
39/39 [==============================] - 0s 550us/step - loss: 0.0216
Epoch 510/800
39/39 [==============================] - 0s 327us/step - loss: 0.0238
Epoch 511/800
39/39 [==============================] - 0s 258us/step - loss: 0.0201
Epoch 512/800
39/39 [==============================] - 0s 365us/step - loss: 0.0177
Epoch 513/800
39/39 [==============================] - 0s 587us/step - loss: 0.0221
Epoch 514/800
39/39 [==============================] - 0s 627us/step - loss: 0.0149
Epoch 515/800
39/39 [==============================] - 0s 351us/step - loss: 0.0281
Epoch 516/800
39/39 [==============================] - 0s 502us/step - loss: 0.0192
Epoch 517/800
39/39 [==============================] - 0s 382us/step - loss: 0.0277
Epoch 518/800
39/39 [==============================] - 0s 528us/step - loss: 0.0285
Epoch 519/800
39/39 [==============================] - 0s 819us/step - loss: 0.0166
Epoch 520/800
39/39 [==============================] - 0s 725us/step - loss: 0.0215
Epoch 521/800
39/39 [==============================] - 0s 417us/step - loss: 0.0326
Epoch 522/800
39/39 [==============================] - 0s 406us/step - loss: 0.0181
Epoch 523/800
39/39 [==============================] - 0s 342us/step - loss: 0.0188
Epoch 524/800
39/39 [==============================] - 0s 393us/step - loss: 0.0241
Epoch 525/800
39/39 [==============================] - 0s 357us/step - loss: 0.0222
Epoch 526/800
39/39 [==============================] - 0s 338us/step - loss: 0.0182
Epoch 527/800
39/39 [==============================] - 0s 430us/step - loss: 0.0164
Epoch 528/800
39/39 [==============================] - 0s 375us/step - loss: 0.0224
```

```
Epoch 529/800
39/39 [==============================] - 0s 279us/step - loss: 0.0259
Epoch 530/800
39/39 [==============================] - 0s 316us/step - loss: 0.0242
Epoch 531/800
39/39 [==============================] - 0s 303us/step - loss: 0.0217
Epoch 532/800
39/39 [==============================] - 0s 407us/step - loss: 0.0192
Epoch 533/800
39/39 [==============================] - 0s 307us/step - loss: 0.0161
Epoch 534/800
39/39 [==============================] - 0s 320us/step - loss: 0.0207
Epoch 535/800
39/39 [==============================] - 0s 352us/step - loss: 0.0145
Epoch 536/800
39/39 [==============================] - 0s 363us/step - loss: 0.0192
Epoch 537/800
39/39 [==============================] - 0s 331us/step - loss: 0.0178
Epoch 538/800
39/39 [==============================] - 0s 357us/step - loss: 0.0254
Epoch 539/800
39/39 [==============================] - 0s 617us/step - loss: 0.0240
Epoch 540/800
39/39 [==============================] - 0s 309us/step - loss: 0.0171
Epoch 541/800
39/39 [==============================] - 0s 287us/step - loss: 0.0219
Epoch 542/800
39/39 [==============================] - 0s 287us/step - loss: 0.0178
Epoch 543/800
39/39 [==============================] - 0s 320us/step - loss: 0.0228
Epoch 544/800
39/39 [==============================] - 0s 331us/step - loss: 0.0220
Epoch 545/800
39/39 [==============================] - 0s 319us/step - loss: 0.0201
Epoch 546/800
39/39 [==============================] - 0s 406us/step - loss: 0.0206
Epoch 547/800
39/39 [==============================] - 0s 873us/step - loss: 0.0258
Epoch 548/800
39/39 [==============================] - 0s 872us/step - loss: 0.0179
Epoch 549/800
39/39 [==============================] - 0s 672us/step - loss: 0.0145
Epoch 550/800
39/39 [==============================] - 0s 396us/step - loss: 0.0226
Epoch 551/800
39/39 [==============================] - 0s 379us/step - loss: 0.0220
Epoch 552/800
39/39 [==============================] - 0s 376us/step - loss: 0.0171
Epoch 553/800
39/39 [==============================] - 0s 503us/step - loss: 0.0226
Epoch 554/800
39/39 [==============================] - 0s 352us/step - loss: 0.0167
Epoch 555/800
39/39 [==============================] - 0s 363us/step - loss: 0.0166
Epoch 556/800
39/39 [==============================] - 0s 429us/step - loss: 0.0202
Epoch 557/800
```

```
39/39 [==============================] - 0s 462us/step - loss: 0.0186
Epoch 558/800
39/39 [==============================] - 0s 426us/step - loss: 0.0310
Epoch 559/800
39/39 [==============================] - 0s 368us/step - loss: 0.0227
Epoch 560/800
39/39 [==============================] - 0s 406us/step - loss: 0.0169
Epoch 561/800
39/39 [==============================] - 0s 371us/step - loss: 0.0247
Epoch 562/800
39/39 [==============================] - 0s 444us/step - loss: 0.0227
Epoch 563/800
39/39 [==============================] - 0s 381us/step - loss: 0.0160
Epoch 564/800
39/39 [==============================] - 0s 352us/step - loss: 0.0187
Epoch 565/800
39/39 [==============================] - 0s 446us/step - loss: 0.0175
Epoch 566/800
39/39 [==============================] - 0s 421us/step - loss: 0.0328
Epoch 567/800
39/39 [==============================] - ETA: 0s - loss: 0.023 - 0s 679us/step
- loss: 0.0216
Epoch 568/800
39/39 [==============================] - 0s 369us/step - loss: 0.0169
Epoch 569/800
39/39 [==============================] - 0s 366us/step - loss: 0.0182
Epoch 570/800
39/39 [==============================] - 0s 637us/step - loss: 0.0259
Epoch 571/800
39/39 [==============================] - 0s 411us/step - loss: 0.0226
Epoch 572/800
39/39 [==============================] - 0s 332us/step - loss: 0.0154
Epoch 573/800
39/39 [==============================] - 0s 377us/step - loss: 0.0228
Epoch 574/800
39/39 [==============================] - 0s 621us/step - loss: 0.0208
Epoch 575/800
39/39 [==============================] - 0s 402us/step - loss: 0.0252
Epoch 576/800
39/39 [==============================] - 0s 371us/step - loss: 0.0146
Epoch 577/800
39/39 [==============================] - 0s 453us/step - loss: 0.0257
Epoch 578/800
39/39 [==============================] - 0s 608us/step - loss: 0.0192
Epoch 579/800
39/39 [==============================] - 0s 408us/step - loss: 0.0296
Epoch 580/800
39/39 [==============================] - 0s 498us/step - loss: 0.0196
Epoch 581/800
39/39 [==============================] - 0s 511us/step - loss: 0.0204
Epoch 582/800
39/39 [==============================] - 0s 2ms/step - loss: 0.0147
Epoch 583/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0198
Epoch 584/800
39/39 [==============================] - 0s 455us/step - loss: 0.0160
Epoch 585/800
```

```
39/39 [==============================] - 0s 471us/step - loss: 0.0231
Epoch 586/800
39/39 [==============================] - 0s 483us/step - loss: 0.0206
Epoch 587/800
39/39 [==============================] - 0s 406us/step - loss: 0.0218
Epoch 588/800
39/39 [==============================] - 0s 439us/step - loss: 0.0153
Epoch 589/800
39/39 [==============================] - 0s 416us/step - loss: 0.0175
Epoch 590/800
39/39 [==============================] - 0s 317us/step - loss: 0.0165
Epoch 591/800
39/39 [==============================] - 0s 417us/step - loss: 0.0231
Epoch 592/800
39/39 [==============================] - 0s 674us/step - loss: 0.0192
Epoch 593/800
39/39 [==============================] - 0s 398us/step - loss: 0.0204
Epoch 594/800
39/39 [==============================] - 0s 358us/step - loss: 0.0291
Epoch 595/800
39/39 [==============================] - 0s 405us/step - loss: 0.0189
Epoch 596/800
39/39 [==============================] - 0s 444us/step - loss: 0.0235
Epoch 597/800
39/39 [==============================] - 0s 526us/step - loss: 0.0249
Epoch 598/800
39/39 [==============================] - 0s 642us/step - loss: 0.0202
Epoch 599/800
39/39 [==============================] - 0s 319us/step - loss: 0.0231
Epoch 600/800
39/39 [==============================] - 0s 464us/step - loss: 0.0169
Epoch 601/800
39/39 [==============================] - 0s 584us/step - loss: 0.0166
Epoch 602/800
39/39 [==============================] - 0s 546us/step - loss: 0.0239
Epoch 603/800
39/39 [==============================] - 0s 447us/step - loss: 0.0186
Epoch 604/800
39/39 [==============================] - 0s 438us/step - loss: 0.0228
Epoch 605/800
39/39 [==============================] - 0s 410us/step - loss: 0.0168
Epoch 606/800
39/39 [==============================] - 0s 561us/step - loss: 0.0238
Epoch 607/800
39/39 [==============================] - ETA: 0s - loss: 0.017 - 0s 455us/step
- loss: 0.0155
Epoch 608/800
39/39 [==============================] - 0s 327us/step - loss: 0.0216
Epoch 609/800
39/39 [==============================] - 0s 746us/step - loss: 0.0135
Epoch 610/800
39/39 [==============================] - 0s 514us/step - loss: 0.0168
Epoch 611/800
39/39 [==============================] - 0s 529us/step - loss: 0.0217
Epoch 612/800
39/39 [==============================] - 0s 525us/step - loss: 0.0129
Epoch 613/800
```

```
39/39 [==============================] - 0s 401us/step - loss: 0.0317
Epoch 614/800
39/39 [==============================] - 0s 377us/step - loss: 0.0138
Epoch 615/800
39/39 [==============================] - 0s 432us/step - loss: 0.0169
Epoch 616/800
39/39 [==============================] - 0s 714us/step - loss: 0.0205
Epoch 617/800
39/39 [==============================] - 0s 447us/step - loss: 0.0171
Epoch 618/800
39/39 [==============================] - 0s 452us/step - loss: 0.0193
Epoch 619/800
39/39 [==============================] - 0s 411us/step - loss: 0.0186
Epoch 620/800
39/39 [==============================] - 0s 456us/step - loss: 0.0155
Epoch 621/800
39/39 [==============================] - 0s 473us/step - loss: 0.0178
Epoch 622/800
39/39 [==============================] - 0s 504us/step - loss: 0.0140
Epoch 623/800
39/39 [==============================] - 0s 466us/step - loss: 0.0141
Epoch 624/800
39/39 [==============================] - 0s 368us/step - loss: 0.0221
Epoch 625/800
39/39 [==============================] - 0s 389us/step - loss: 0.0267
Epoch 626/800
39/39 [==============================] - 0s 442us/step - loss: 0.0161
Epoch 627/800
39/39 [==============================] - 0s 507us/step - loss: 0.0158
Epoch 628/800
39/39 [==============================] - 0s 629us/step - loss: 0.0172
Epoch 629/800
39/39 [==============================] - 0s 403us/step - loss: 0.0168
Epoch 630/800
39/39 [==============================] - 0s 376us/step - loss: 0.0227
Epoch 631/800
39/39 [==============================] - 0s 418us/step - loss: 0.0134
Epoch 632/800
39/39 [==============================] - 0s 409us/step - loss: 0.0190
Epoch 633/800
39/39 [==============================] - 0s 432us/step - loss: 0.0214
Epoch 634/800
39/39 [==============================] - 0s 520us/step - loss: 0.0202
Epoch 635/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0165
Epoch 636/800
39/39 [==============================] - 0s 679us/step - loss: 0.0189
Epoch 637/800
39/39 [==============================] - 0s 644us/step - loss: 0.0172
Epoch 638/800
39/39 [==============================] - 0s 644us/step - loss: 0.0198
Epoch 639/800
39/39 [==============================] - 0s 639us/step - loss: 0.0156
Epoch 640/800
39/39 [==============================] - 0s 426us/step - loss: 0.0234
Epoch 641/800
39/39 [==============================] - 0s 359us/step - loss: 0.0235
```

```
Epoch 642/800
39/39 [==============================] - 0s 383us/step - loss: 0.0223
Epoch 643/800
39/39 [==============================] - 0s 444us/step - loss: 0.0160
Epoch 644/800
39/39 [==============================] - 0s 407us/step - loss: 0.0243
Epoch 645/800
39/39 [==============================] - 0s 392us/step - loss: 0.0211
Epoch 646/800
39/39 [==============================] - 0s 472us/step - loss: 0.0160
Epoch 647/800
39/39 [==============================] - 0s 365us/step - loss: 0.0254
Epoch 648/800
39/39 [==============================] - 0s 272us/step - loss: 0.0185
Epoch 649/800
39/39 [==============================] - 0s 307us/step - loss: 0.0201
Epoch 650/800
39/39 [==============================] - 0s 332us/step - loss: 0.0230
Epoch 651/800
39/39 [==============================] - 0s 322us/step - loss: 0.0125
Epoch 652/800
39/39 [==============================] - 0s 296us/step - loss: 0.0204
Epoch 653/800
39/39 [==============================] - 0s 318us/step - loss: 0.0136
Epoch 654/800
39/39 [==============================] - 0s 416us/step - loss: 0.0182
Epoch 655/800
39/39 [==============================] - 0s 472us/step - loss: 0.0188
Epoch 656/800
39/39 [==============================] - 0s 768us/step - loss: 0.0167
Epoch 657/800
39/39 [==============================] - 0s 440us/step - loss: 0.0172
Epoch 658/800
39/39 [==============================] - 0s 510us/step - loss: 0.0160
Epoch 659/800
39/39 [==============================] - 0s 393us/step - loss: 0.0246
Epoch 660/800
39/39 [==============================] - 0s 293us/step - loss: 0.0243
Epoch 661/800
39/39 [==============================] - 0s 311us/step - loss: 0.0200
Epoch 662/800
39/39 [==============================] - 0s 337us/step - loss: 0.0182
Epoch 663/800
39/39 [==============================] - 0s 336us/step - loss: 0.0146
Epoch 664/800
39/39 [==============================] - 0s 382us/step - loss: 0.0194
Epoch 665/800
39/39 [==============================] - 0s 488us/step - loss: 0.0166
Epoch 666/800
39/39 [==============================] - 0s 316us/step - loss: 0.0194
Epoch 667/800
39/39 [==============================] - 0s 392us/step - loss: 0.0346
Epoch 668/800
39/39 [==============================] - 0s 510us/step - loss: 0.0186
Epoch 669/800
39/39 [==============================] - 0s 314us/step - loss: 0.0160
Epoch 670/800
```

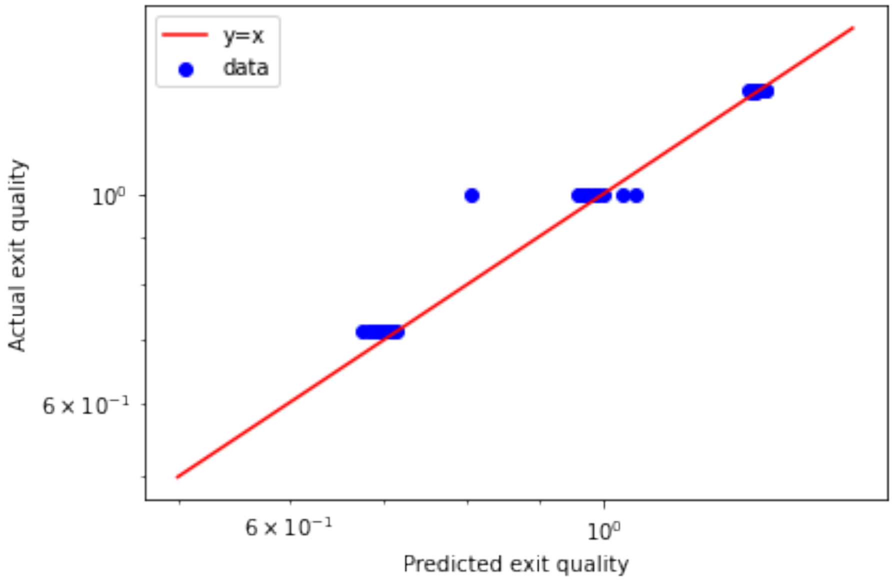
```
39/39 [==============================] - 0s 358us/step - loss: 0.0174
Epoch 671/800
39/39 [==============================] - 0s 403us/step - loss: 0.0161
Epoch 672/800
39/39 [==============================] - 0s 347us/step - loss: 0.0126
Epoch 673/800
39/39 [==============================] - 0s 373us/step - loss: 0.0221
Epoch 674/800
39/39 [==============================] - 0s 736us/step - loss: 0.0215
Epoch 675/800
39/39 [==============================] - 0s 920us/step - loss: 0.0170
Epoch 676/800
39/39 [==============================] - 0s 881us/step - loss: 0.0136
Epoch 677/800
39/39 [==============================] - 0s 578us/step - loss: 0.0214
Epoch 678/800
39/39 [==============================] - ETA: 0s - loss: 0.020 - 0s 557us/step
- loss: 0.0184
Epoch 679/800
39/39 [==============================] - 0s 662us/step - loss: 0.0203
Epoch 680/800
39/39 [==============================] - 0s 406us/step - loss: 0.0199
Epoch 681/800
39/39 [==============================] - 0s 518us/step - loss: 0.0209
Epoch 682/800
39/39 [==============================] - 0s 301us/step - loss: 0.0148
Epoch 683/800
39/39 [==============================] - 0s 327us/step - loss: 0.0242
Epoch 684/800
39/39 [==============================] - 0s 356us/step - loss: 0.0222
Epoch 685/800
39/39 [==============================] - 0s 348us/step - loss: 0.0279
Epoch 686/800
39/39 [==============================] - 0s 386us/step - loss: 0.0185
Epoch 687/800
39/39 [==============================] - 0s 378us/step - loss: 0.0145
Epoch 688/800
39/39 [==============================] - 0s 339us/step - loss: 0.0182
Epoch 689/800
39/39 [==============================] - 0s 432us/step - loss: 0.0216
Epoch 690/800
39/39 [==============================] - 0s 611us/step - loss: 0.0171
Epoch 691/800
39/39 [==============================] - 0s 545us/step - loss: 0.0163
Epoch 692/800
39/39 [==============================] - 0s 864us/step - loss: 0.0196
Epoch 693/800
39/39 [==============================] - 0s 611us/step - loss: 0.0153
Epoch 694/800
39/39 [==============================] - 0s 360us/step - loss: 0.0208
Epoch 695/800
39/39 [==============================] - 0s 432us/step - loss: 0.0206
Epoch 696/800
39/39 [==============================] - 0s 423us/step - loss: 0.0210
Epoch 697/800
39/39 [==============================] - 0s 463us/step - loss: 0.0258
Epoch 698/800
```

```
39/39 [==============================] - 0s 441us/step - loss: 0.0156
Epoch 699/800
39/39 [==============================] - 0s 568us/step - loss: 0.0165
Epoch 700/800
39/39 [==============================] - 0s 759us/step - loss: 0.0211
Epoch 701/800
39/39 [==============================] - 0s 767us/step - loss: 0.0211
Epoch 702/800
39/39 [==============================] - 0s 664us/step - loss: 0.0177
Epoch 703/800
39/39 [==============================] - 0s 360us/step - loss: 0.0199
Epoch 704/800
39/39 [==============================] - 0s 273us/step - loss: 0.0143
Epoch 705/800
39/39 [==============================] - 0s 367us/step - loss: 0.0147
Epoch 706/800
39/39 [==============================] - 0s 312us/step - loss: 0.0192
Epoch 707/800
39/39 [==============================] - 0s 248us/step - loss: 0.0227
Epoch 708/800
39/39 [==============================] - 0s 284us/step - loss: 0.0157
Epoch 709/800
39/39 [==============================] - 0s 390us/step - loss: 0.0135
Epoch 710/800
39/39 [==============================] - 0s 325us/step - loss: 0.0212
Epoch 711/800
39/39 [==============================] - 0s 237us/step - loss: 0.0168
Epoch 712/800
39/39 [==============================] - 0s 338us/step - loss: 0.0183
Epoch 713/800
39/39 [==============================] - 0s 370us/step - loss: 0.0191
Epoch 714/800
39/39 [==============================] - 0s 312us/step - loss: 0.0259
Epoch 715/800
39/39 [==============================] - 0s 386us/step - loss: 0.0159
Epoch 716/800
39/39 [==============================] - 0s 432us/step - loss: 0.0248
Epoch 717/800
39/39 [==============================] - 0s 301us/step - loss: 0.0178
Epoch 718/800
39/39 [==============================] - 0s 280us/step - loss: 0.0221
Epoch 719/800
39/39 [==============================] - 0s 299us/step - loss: 0.0190
Epoch 720/800
39/39 [==============================] - 0s 370us/step - loss: 0.0190
Epoch 721/800
39/39 [==============================] - 0s 346us/step - loss: 0.0243
Epoch 722/800
39/39 [==============================] - 0s 318us/step - loss: 0.0190
Epoch 723/800
39/39 [==============================] - 0s 285us/step - loss: 0.0131
Epoch 724/800
39/39 [==============================] - 0s 237us/step - loss: 0.0147
Epoch 725/800
39/39 [==============================] - 0s 271us/step - loss: 0.0206
Epoch 726/800
39/39 [==============================] - 0s 271us/step - loss: 0.0207
```

```
Epoch 727/800
39/39 [==============================] - 0s 262us/step - loss: 0.0194
Epoch 728/800
39/39 [==============================] - 0s 288us/step - loss: 0.0139
Epoch 729/800
39/39 [==============================] - 0s 260us/step - loss: 0.0227
Epoch 730/800
39/39 [==============================] - 0s 303us/step - loss: 0.0193
Epoch 731/800
39/39 [==============================] - 0s 756us/step - loss: 0.0141
Restoring model weights from the end of the best epoch
Epoch 00731: early stopping
best epoch =  651
smallest loss = 0.012513714746978039
```

In [108…

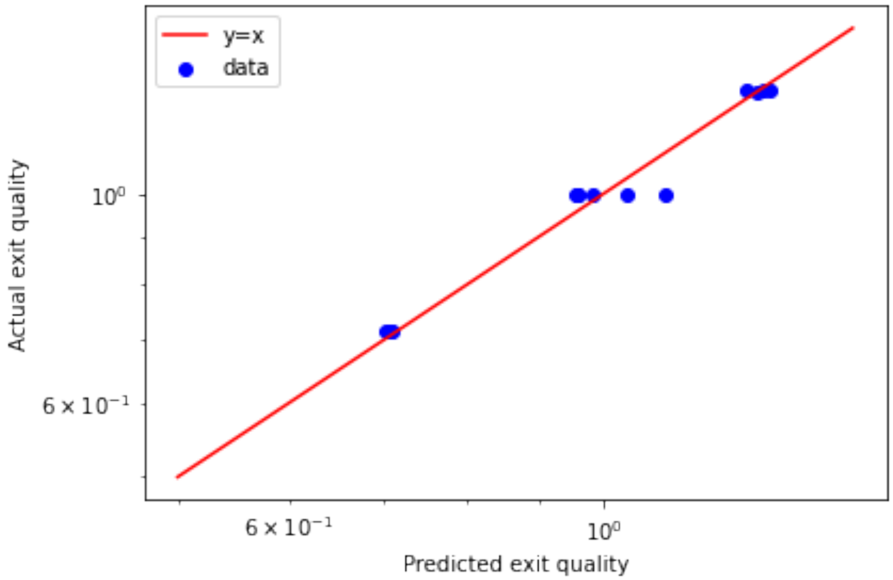
```
# Task 1.1e
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model = keras.models.load_model("best_model")

import matplotlib.pyplot as plt

y_predict = []
xepred = []
xeorig = []

for i in range(len(X_train)):
    test = [[X_train[i][0], X_train[i][1], X_train[i][2]]]
    testarray = np.array(test)
    a = recon_model.predict(testarray)
    y_predict.append([a[0][0], a[0][1]])
    xepred.append([a[0][0]])
    xeorig.append([y_train[i][0]])

x = np.linspace(0.5,1.5,100)
y = x

plt.figure()
ax = plt.gca()
ax.scatter(xepred ,xeorig , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.plot(x, y, '-r', label='y=x')
plt.xlabel("Predicted exit quality")
plt.ylabel("Actual exit quality")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_xe = metrics.mean_absolute_error(xepred,xeorig)
print('mean absolute error between predictions and the collection of test dat
```




```
mean absolute error between predictions and the collection of test data: Xe =
0.02350722758865225
```

In [109…

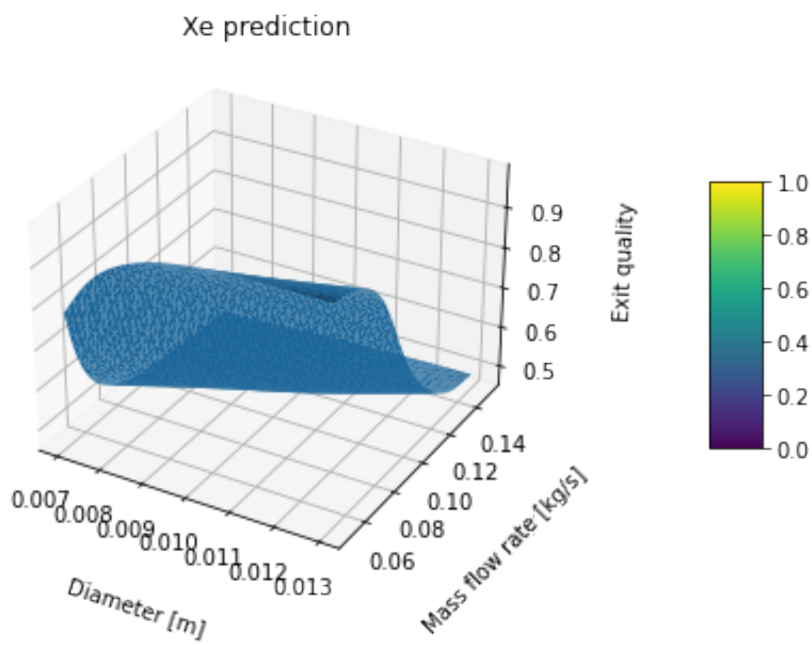
```
# Task 1.1f
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model = keras.models.load_model("best_model")

import matplotlib.pyplot as plt

y_predictf = []
xepredf = []
xeorigf = []

for i in range(len(X_test)):
    testf = [[X_test[i][0], X_test[i][1], X_test[i][2]]]
    testarrayf = np.array(testf)
    af = recon_model.predict(testarrayf)
    y_predictf.append([af[0][0], af[0][1]])
    xepredf.append([af[0][0]])
    xeorigf.append([y_test[i][0]])

x = np.linspace(0.5,1.5,100)
y = x

plt.figure()
ax = plt.gca()
ax.scatter(xepredf ,xeorigf , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.plot(x, y, '-r', label='y=x')
plt.xlabel("Predicted exit quality")
plt.ylabel("Actual exit quality")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_xef = metrics.mean_absolute_error(xepredf,xeorigf)
print('mean absolute error between predictions and the collection of test dat
```




```
mean absolute error between predictions and the collection of test data: Xe =
0.029029867787563276
```

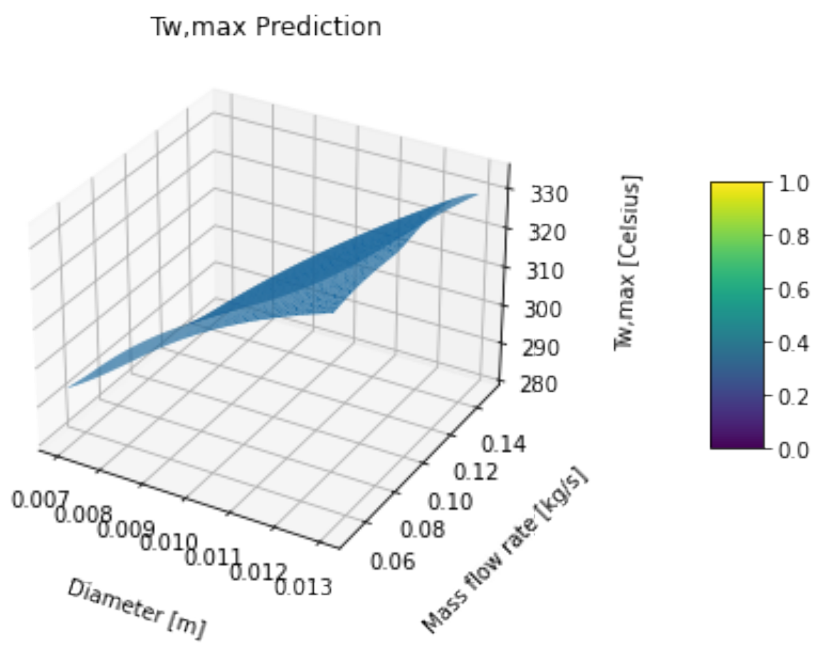
In [170…

```
#Task1.1g
X = np.linspace(0.007, 0.013) #Di
Y = np.linspace(0.05, 0.15) #mdot
q0 = 750

Xp = [] #input
Yp = []
testdatap = []
xep = [] #output
Twp = []
preddatap = []

q0n = q0/medq0
Xn = X/medDi
Yn = Y/medmdot

for x in range(len(Xn)):
    for y in range(len(Yn)):
        testdatap.append([Xn[x], q0n, Yn[y]])

Xp = np.asarray(testdatap)[:,0]*medDi
Yp = np.asarray(testdatap)[:,2]*medmdot

for x in range(len(testdatap)):
    testp = [[testdatap[x][0], testdatap[x][1], testdatap[x][2]]]
    testarrayp = np.array(testp)
    outptp = recon_model.predict(testarrayp)
    preddatap.append(outptp)
    xep.append(outptp[0][0]*medxe)
    Twp.append(outptp[0][1]*medTw)

fig = plt.figure()
ax = plt.axes(projection='3d')
surf = ax.plot_trisurf(Xp, Yp, xep)
fig.colorbar(surf, shrink=0.5, aspect=5, pad=0.2)
ax.set_zlabel('Exit quality', rotation=60)
ax.set_ylabel('Mass flow rate [kg/s]')
ax.set_xlabel('Diameter [m]', rotation=150)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.zaxis.labelpad=15
ax.title.set_text('Xe prediction');
plt.tight_layout()
plt.show()
```



In [171…

```
fig = plt.figure()
ax = plt.axes(projection='3d')
surf = ax.plot_trisurf(Xp, Yp, Twp)
fig.colorbar(surf, shrink=0.5, aspect=5, pad=0.2)
ax.set_zlabel('Tw,max [Celsius]', rotation=60)
ax.set_ylabel('Mass flow rate [kg/s]')
ax.set_xlabel('Diameter [m]', rotation=150)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.zaxis.labelpad=15
ax.title.set_text('Tw,max Prediction');
plt.tight_layout()
plt.show()
```



In [254…

```
#Task1.2a-c
# define neural network model

from keras import backend as K
from keras.layers import Dense, Dropout, Flatten
#initialize weights
initializer = keras.initializers.RandomUniform(minval= -0.2, maxval=0.5)

modelv2 = keras.Sequential()
modelv2.add(Dense(6, activation=K.elu, input_shape=[3],  kernel_initializer=i
modelv2.add(Dense(8, activation=K.elu,  kernel_initializer=initializer))
modelv2.add(Dropout(0.25))
modelv2.add(Dense(12, activation=K.elu, kernel_initializer=initializer))
modelv2.add(Dropout(0.25))
modelv2.add(Dense(16, activation=K.elu, kernel_initializer=initializer))
modelv2.add(Dropout(0.25))
modelv2.add(Dense(8, activation=K.elu,  kernel_initializer=initializer))
modelv2.add(Dropout(0.25))
modelv2.add(Dense(2,  kernel_initializer=initializer))
```

In [257…

```
#from tf.keras import optimizers
rms = keras.optimizers.RMSprop(0.001)
modelv2.compile(loss='mean_absolute_error',optimizer=rms)
```

In [258…

```
# Add an early stopping callback
es = keras.callbacks.EarlyStopping(
    monitor='loss',
    mode='min',
    patience = 80,
    restore_best_weights = True,
    verbose=1)
# Add a checkpoint where loss is minimum, and save that model
mc = keras.callbacks.ModelCheckpoint('best_modelv2.SB', monitor='loss',
                     mode='min',  verbose=1, save_best_only=True)

historyDatav2 = modelv2.fit(X_train,y_train,epochs=800,callbacks=[es])

loss_histv2 = historyDatav2.history['loss']
#The above line will return a dictionary, access it's info like this:
best_epochv2 = np.argmin(historyDatav2.history['loss']) + 1
print ('best epoch = ', best_epochv2)
print('smallest loss =', np.min(loss_histv2))

model.save('./best_modelv2')
```

```
Epoch 1/800
39/39 [==============================] - 3s 77ms/step - loss: 0.1947
Epoch 2/800
39/39 [==============================] - 0s 780us/step - loss: 0.1839
Epoch 3/800
39/39 [==============================] - 0s 482us/step - loss: 0.1702
Epoch 4/800
39/39 [==============================] - 0s 802us/step - loss: 0.1679
Epoch 5/800
39/39 [==============================] - 0s 699us/step - loss: 0.1767
Epoch 6/800
39/39 [==============================] - 0s 510us/step - loss: 0.1378
Epoch 7/800
39/39 [==============================] - 0s 2ms/step - loss: 0.1679
Epoch 8/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1539
Epoch 9/800
39/39 [==============================] - 0s 819us/step - loss: 0.1512
Epoch 10/800
39/39 [==============================] - 0s 611us/step - loss: 0.1828
Epoch 11/800
39/39 [==============================] - 0s 482us/step - loss: 0.1871
Epoch 12/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1466
Epoch 13/800
39/39 [==============================] - 0s 867us/step - loss: 0.1438
Epoch 14/800
39/39 [==============================] - 0s 454us/step - loss: 0.1836
Epoch 15/800
39/39 [==============================] - 0s 432us/step - loss: 0.1548
Epoch 16/800
39/39 [==============================] - 0s 998us/step - loss: 0.1618
Epoch 17/800
```

```
39/39 [==============================] - 0s 471us/step - loss: 0.1911
Epoch 18/800
39/39 [==============================] - 0s 436us/step - loss: 0.1672
Epoch 19/800
39/39 [==============================] - 0s 520us/step - loss: 0.1597
Epoch 20/800
39/39 [==============================] - 0s 426us/step - loss: 0.1518
Epoch 21/800
39/39 [==============================] - 0s 552us/step - loss: 0.1837
Epoch 22/800
39/39 [==============================] - 0s 633us/step - loss: 0.1543
Epoch 23/800
39/39 [==============================] - ETA: 0s - loss: 0.190 - 0s 777us/step
- loss: 0.1799
Epoch 24/800
39/39 [==============================] - 0s 418us/step - loss: 0.1515
Epoch 25/800
39/39 [==============================] - 0s 686us/step - loss: 0.1691
Epoch 26/800
39/39 [==============================] - 0s 410us/step - loss: 0.1690
Epoch 27/800
39/39 [==============================] - 0s 367us/step - loss: 0.1553
Epoch 28/800
39/39 [==============================] - 0s 414us/step - loss: 0.1678
Epoch 29/800
39/39 [==============================] - 0s 414us/step - loss: 0.1457
Epoch 30/800
39/39 [==============================] - 0s 519us/step - loss: 0.1652
Epoch 31/800
39/39 [==============================] - 0s 371us/step - loss: 0.1994
Epoch 32/800
39/39 [==============================] - 0s 373us/step - loss: 0.1741
Epoch 33/800
39/39 [==============================] - 0s 471us/step - loss: 0.1688
Epoch 34/800
39/39 [==============================] - 0s 573us/step - loss: 0.1773
Epoch 35/800
39/39 [==============================] - 0s 425us/step - loss: 0.1540
Epoch 36/800
39/39 [==============================] - 0s 487us/step - loss: 0.1623
Epoch 37/800
39/39 [==============================] - 0s 553us/step - loss: 0.1664
Epoch 38/800
39/39 [==============================] - 0s 503us/step - loss: 0.1483
Epoch 39/800
39/39 [==============================] - 0s 548us/step - loss: 0.1521
Epoch 40/800
39/39 [==============================] - 0s 516us/step - loss: 0.1793
Epoch 41/800
39/39 [==============================] - 0s 486us/step - loss: 0.1702
Epoch 42/800
39/39 [==============================] - 0s 614us/step - loss: 0.1595
Epoch 43/800
39/39 [==============================] - 0s 688us/step - loss: 0.1608
Epoch 44/800
39/39 [==============================] - 0s 501us/step - loss: 0.1786
Epoch 45/800
```

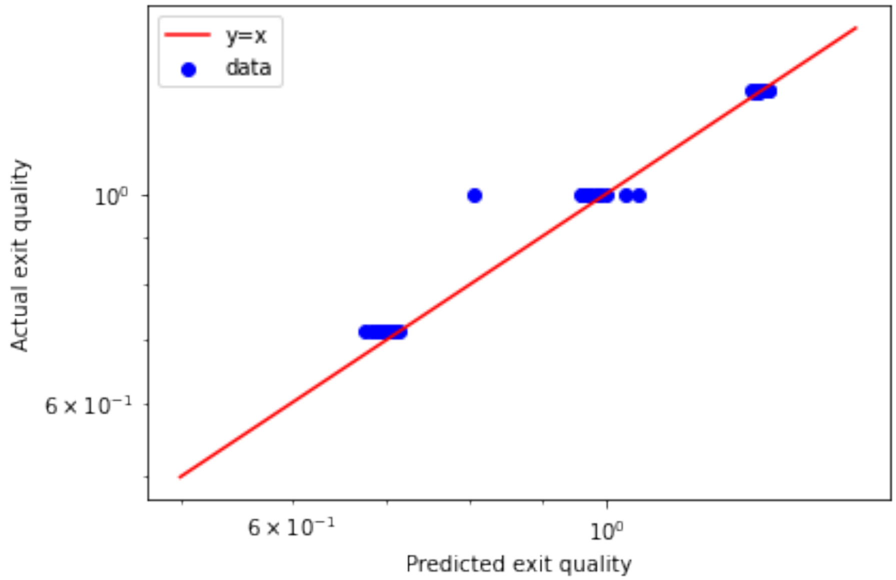
```
39/39 [==============================] - 0s 578us/step - loss: 0.1573
Epoch 46/800
39/39 [==============================] - 0s 721us/step - loss: 0.1239
Epoch 47/800
39/39 [==============================] - 0s 549us/step - loss: 0.1835
Epoch 48/800
39/39 [==============================] - 0s 811us/step - loss: 0.1714
Epoch 49/800
39/39 [==============================] - 0s 702us/step - loss: 0.1567
Epoch 50/800
39/39 [==============================] - 0s 614us/step - loss: 0.1624
Epoch 51/800
39/39 [==============================] - 0s 658us/step - loss: 0.1555
Epoch 52/800
39/39 [==============================] - 0s 564us/step - loss: 0.1712
Epoch 53/800
39/39 [==============================] - 0s 859us/step - loss: 0.1586
Epoch 54/800
39/39 [==============================] - 0s 785us/step - loss: 0.1619
Epoch 55/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1632
Epoch 56/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1413
Epoch 57/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1478
Epoch 58/800
39/39 [==============================] - 0s 578us/step - loss: 0.1451
Epoch 59/800
39/39 [==============================] - 0s 493us/step - loss: 0.1581
Epoch 60/800
39/39 [==============================] - 0s 511us/step - loss: 0.1637
Epoch 61/800
39/39 [==============================] - 0s 549us/step - loss: 0.1662
Epoch 62/800
39/39 [==============================] - 0s 512us/step - loss: 0.1383
Epoch 63/800
39/39 [==============================] - 0s 503us/step - loss: 0.1450
Epoch 64/800
39/39 [==============================] - 0s 660us/step - loss: 0.1568
Epoch 65/800
39/39 [==============================] - 0s 453us/step - loss: 0.1529
Epoch 66/800
39/39 [==============================] - 0s 450us/step - loss: 0.1522
Epoch 67/800
39/39 [==============================] - 0s 564us/step - loss: 0.1822
Epoch 68/800
39/39 [==============================] - 0s 737us/step - loss: 0.1448
Epoch 69/800
39/39 [==============================] - 0s 770us/step - loss: 0.1817
Epoch 70/800
39/39 [==============================] - 0s 449us/step - loss: 0.1317
Epoch 71/800
39/39 [==============================] - 0s 468us/step - loss: 0.1815
Epoch 72/800
39/39 [==============================] - 0s 598us/step - loss: 0.1391
Epoch 73/800
39/39 [==============================] - 0s 716us/step - loss: 0.1484
```

```
Epoch 74/800
39/39 [==============================] - 0s 523us/step - loss: 0.1286
Epoch 75/800
39/39 [==============================] - 0s 380us/step - loss: 0.1447
Epoch 76/800
39/39 [==============================] - 0s 403us/step - loss: 0.1466
Epoch 77/800
39/39 [==============================] - 0s 405us/step - loss: 0.1566
Epoch 78/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1534
Epoch 79/800
39/39 [==============================] - 0s 544us/step - loss: 0.1323
Epoch 80/800
39/39 [==============================] - 0s 564us/step - loss: 0.1484
Epoch 81/800
39/39 [==============================] - 0s 613us/step - loss: 0.1503
Epoch 82/800
39/39 [==============================] - 0s 481us/step - loss: 0.1509
Epoch 83/800
39/39 [==============================] - 0s 1ms/step - loss: 0.1497
Epoch 84/800
39/39 [==============================] - 0s 934us/step - loss: 0.1389
Epoch 85/800
39/39 [==============================] - 0s 677us/step - loss: 0.1620
Epoch 86/800
39/39 [==============================] - 0s 775us/step - loss: 0.1512
Epoch 87/800
39/39 [==============================] - 0s 749us/step - loss: 0.1597
Epoch 88/800
39/39 [==============================] - 0s 714us/step - loss: 0.1636
Epoch 89/800
39/39 [==============================] - 0s 616us/step - loss: 0.1860
Epoch 90/800
39/39 [==============================] - 0s 475us/step - loss: 0.1513
Epoch 91/800
39/39 [==============================] - 0s 587us/step - loss: 0.1280
Epoch 92/800
39/39 [==============================] - 0s 480us/step - loss: 0.1435
Epoch 93/800
39/39 [==============================] - 0s 492us/step - loss: 0.1701
Epoch 94/800
39/39 [==============================] - 0s 551us/step - loss: 0.1587
Epoch 95/800
39/39 [==============================] - 0s 622us/step - loss: 0.1411
Epoch 96/800
39/39 [==============================] - 0s 668us/step - loss: 0.1393
Epoch 97/800
39/39 [==============================] - 0s 729us/step - loss: 0.1373
Epoch 98/800
39/39 [==============================] - 0s 652us/step - loss: 0.1426
Epoch 99/800
39/39 [==============================] - 0s 466us/step - loss: 0.1510
Epoch 100/800
39/39 [==============================] - 0s 605us/step - loss: 0.1441
Epoch 101/800
39/39 [==============================] - 0s 616us/step - loss: 0.1471
Epoch 102/800
```

```
39/39 [==============================] - 0s 781us/step - loss: 0.1630
Epoch 103/800
39/39 [==============================] - 0s 500us/step - loss: 0.1482
Epoch 104/800
39/39 [==============================] - 0s 542us/step - loss: 0.1545
Epoch 105/800
39/39 [==============================] - 0s 574us/step - loss: 0.1475
Epoch 106/800
39/39 [==============================] - 0s 478us/step - loss: 0.1454
Epoch 107/800
39/39 [==============================] - 0s 800us/step - loss: 0.1418
Epoch 108/800
39/39 [==============================] - 0s 476us/step - loss: 0.1812
Epoch 109/800
39/39 [==============================] - 0s 495us/step - loss: 0.1599
Epoch 110/800
39/39 [==============================] - 0s 546us/step - loss: 0.1537
Epoch 111/800
39/39 [==============================] - 0s 466us/step - loss: 0.1485
Epoch 112/800
39/39 [==============================] - 0s 421us/step - loss: 0.1360
Epoch 113/800
39/39 [==============================] - 0s 415us/step - loss: 0.1362
Epoch 114/800
39/39 [==============================] - 0s 451us/step - loss: 0.1871
Epoch 115/800
39/39 [==============================] - 0s 522us/step - loss: 0.1458
Epoch 116/800
39/39 [==============================] - 0s 493us/step - loss: 0.1464
Epoch 117/800
39/39 [==============================] - 0s 468us/step - loss: 0.1462
Epoch 118/800
39/39 [==============================] - 0s 410us/step - loss: 0.1877
Epoch 119/800
39/39 [==============================] - 0s 497us/step - loss: 0.1450
Epoch 120/800
39/39 [==============================] - 0s 501us/step - loss: 0.1451
Epoch 121/800
39/39 [==============================] - 0s 522us/step - loss: 0.1340
Epoch 122/800
39/39 [==============================] - 0s 536us/step - loss: 0.1382
Epoch 123/800
39/39 [==============================] - 0s 433us/step - loss: 0.1431
Epoch 124/800
39/39 [==============================] - 0s 497us/step - loss: 0.1536
Epoch 125/800
39/39 [==============================] - 0s 599us/step - loss: 0.1473
Epoch 126/800
39/39 [==============================] - 0s 753us/step - loss: 0.1455
Restoring model weights from the end of the best epoch
Epoch 00126: early stopping
best epoch =  46
smallest loss = 0.12392662733029096
```

In [250…

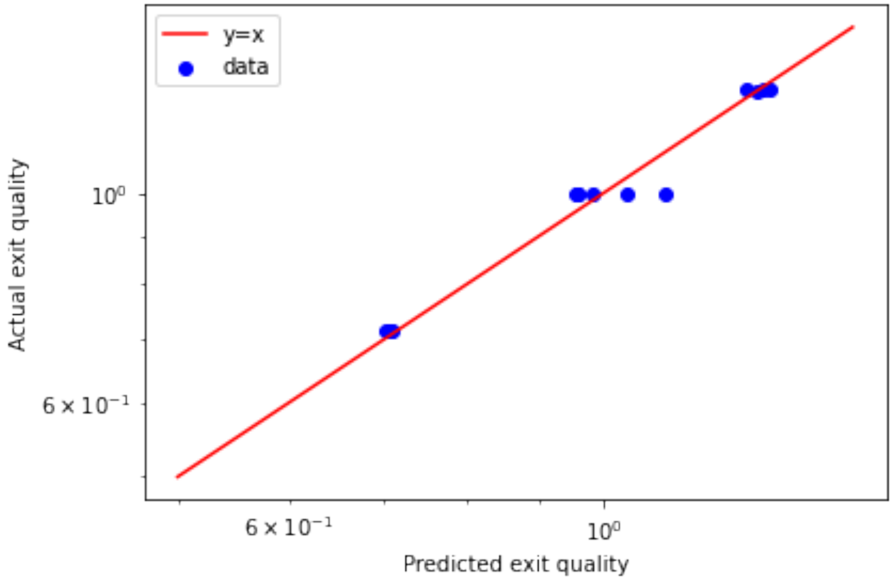
```
# Task 1.2e
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_modelv2 = keras.models.load_model("best_modelv2")

import matplotlib.pyplot as plt

y_predict2 = []
xepred2 = []
xeorig2 = []

for i in range(len(X_train)):
    test = [[X_train[i][0], X_train[i][1], X_train[i][2]]]
    testarray = np.array(test)
    a = recon_modelv2.predict(testarray)
    y_predict2.append([a[0][0], a[0][1]])
    xepred2.append([a[0][0]])
    xeorig2.append([y_train[i][0]])

x = np.linspace(0.5,1.5,100)
y = x

plt.figure()
ax = plt.gca()
ax.scatter(xepred2 ,xeorig2 , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.plot(x, y, '-r', label='y=x')
plt.xlabel("Predicted exit quality")
plt.ylabel("Actual exit quality")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_xe2 = metrics.mean_absolute_error(xepred2,xeorig2)
print('mean absolute error between predictions and the collection of test dat
```



mean absolute error between predictions and the collection of test data: Xe = 0.02350722758865225

In [251…

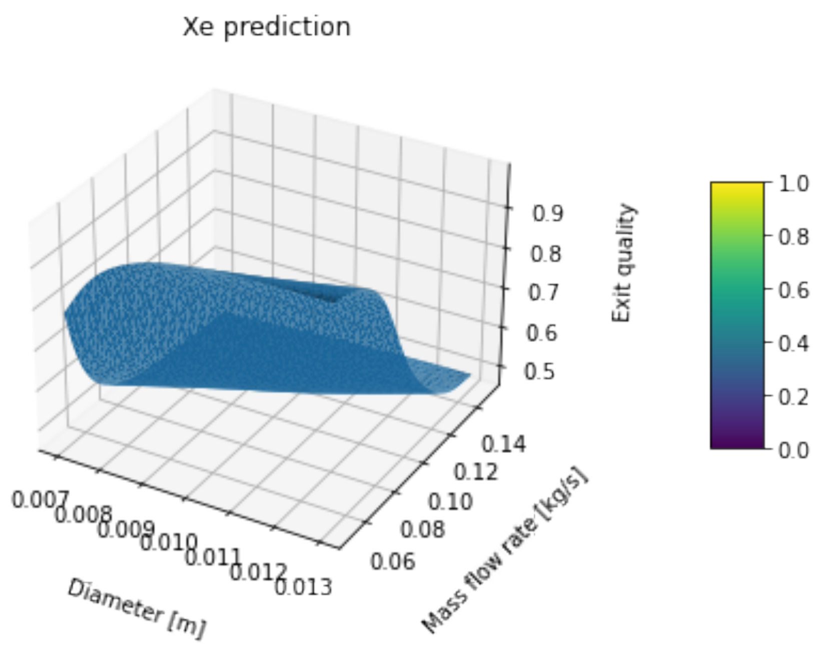
```
# Task 1.2f
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_modelv2 = keras.models.load_model("best_modelv2")

import matplotlib.pyplot as plt

y_predictf2 = []
xepredf2 = []
xeorigf2 = []

for i in range(len(X_test)):
    testf = [[X_test[i][0], X_test[i][1], X_test[i][2]]]
    testarrayf = np.array(testf)
    af = recon_modelv2.predict(testarrayf)
    y_predictf2.append([af[0][0], af[0][1]])
    xepredf2.append([af[0][0]])
    xeorigf2.append([y_test[i][0]])

x = np.linspace(0.5,1.5,100)
y = x

plt.figure()
ax = plt.gca()
ax.scatter(xepredf2 ,xeorigf2 , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.plot(x, y, '-r', label='y=x')
plt.xlabel("Predicted exit quality")
plt.ylabel("Actual exit quality")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_xef2 = metrics.mean_absolute_error(xepredf2,xeorigf2)
print('mean absolute error between predictions and the collection of test dat
```



mean absolute error between predictions and the collection of test data: Xe = 0.029029867787563276

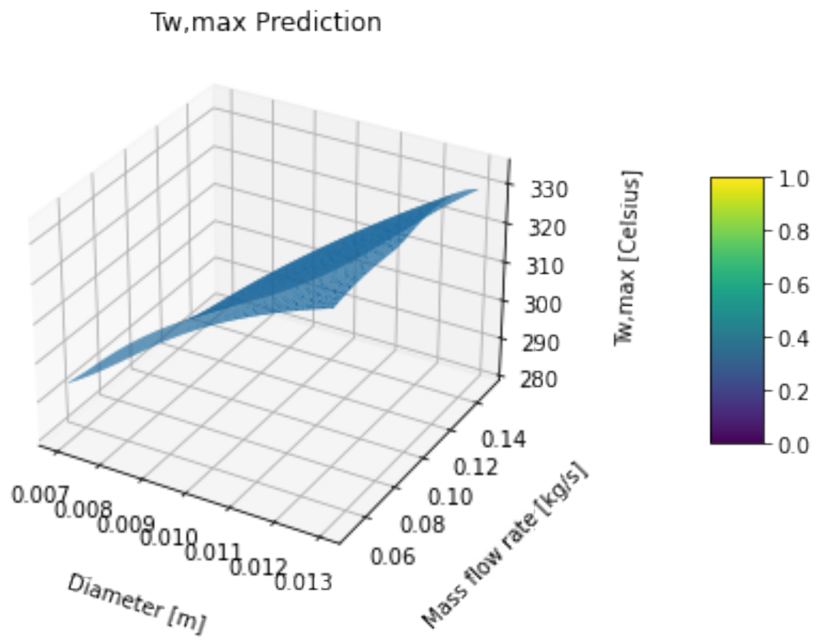
In [252…

```
#Task1.2g
X = np.linspace(0.007, 0.013) #Di
Y = np.linspace(0.05, 0.15) #mdot
q0 = 750

testdatap = []
xep2 = [] #output
Twp2 = []
preddatap2 = []

q0n = q0/medq0
Xn = X/medDi
Yn = Y/medmdot

for x in range(len(Xn)):
    for y in range(len(Yn)):
        testdatap.append([Xn[x], q0n, Yn[y]])

Xp = np.asarray(testdatap)[:,0]*medDi
Yp = np.asarray(testdatap)[:,2]*medmdot

for x in range(len(testdatap)):
    testp = [[testdatap[x][0], testdatap[x][1], testdatap[x][2]]]
    testarrayp = np.array(testp)
    outptp = recon_modelv2.predict(testarrayp)
    preddatap2.append(outptp)
    xep2.append(outptp[0][0]*medxe)
    Twp2.append(outptp[0][1]*medTw)

fig = plt.figure()
ax = plt.axes(projection='3d')
surf = ax.plot_trisurf(Xp, Yp, xep2)
fig.colorbar(surf, shrink=0.5, aspect=5, pad=0.2)
ax.set_zlabel('Exit quality', rotation=60)
ax.set_ylabel('Mass flow rate [kg/s]')
ax.set_xlabel('Diameter [m]', rotation=150)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.zaxis.labelpad=15
ax.title.set_text('Xe prediction');
plt.tight_layout()
plt.show()
```



In [253…

```
fig = plt.figure()
ax = plt.axes(projection='3d')
surf = ax.plot_trisurf(Xp, Yp, Twp2)
fig.colorbar(surf, shrink=0.5, aspect=5, pad=0.2)
ax.set_zlabel('Tw,max [Celsius]', rotation=60)
ax.set_ylabel('Mass flow rate [kg/s]')
ax.set_xlabel('Diameter [m]', rotation=150)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.zaxis.labelpad=15
ax.title.set_text('Tw,max Prediction');
plt.tight_layout()
plt.show()
```



In [13]:

```
#Task1.3
import numpy

xdata = []
ydata = []
#xdata.append([ Di(m), qoflux (kW/m^2), exit quality, max wall temperature (d

xdata.append([0.008, 550, 0.525, 306.7])
xdata.append([0.008, 650, 0.525, 298.5])
xdata.append([0.008, 750, 0.525, 294.5])
xdata.append([0.008, 850, 0.525, 290.2])
xdata.append([0.008, 950, 0.524, 286.9])
xdata.append([0.008, 1050, 0.524, 284.1])
xdata.append([0.008, 1150, 0.525, 281.7])
xdata.append([0.008, 850, 0.524, 290.31])
xdata.append([0.008, 550, 0.734, 307.9])
xdata.append([0.008, 750, 0.735, 295.5])
xdata.append([0.008, 950, 0.735, 287.8])
xdata.append([0.008, 1050, 0.735, 285.0])
xdata.append([0.008, 1150, 0.735, 282.5])
xdata.append([0.008, 850, 0.734, 291.3])
xdata.append([0.008, 550,  0.945, 308.6])
xdata.append([0.008, 750, 0.945, 296.2])
xdata.append([0.008, 950, 0.945, 288.5])
xdata.append([0.008, 1150, 0.945, 283.1])
xdata.append([0.008, 850, 0.945, 291.9])
xdata.append([0.011, 550,  0.525, 328.0])
xdata.append([0.011, 750, 0.525, 311.2])
xdata.append([0.011, 950, 0.525, 300.8])
xdata.append([0.011, 1150, 0.525, 293.6])
xdata.append([0.011, 850, 0.525, 305.5])
xdata.append([0.011, 550, 0.735, 329.6])
```

```
xdata.append([0.011, 750, 0.735, 312.6])
xdata.append([0.011, 950, 0.735, 302.0])
xdata.append([0.011, 1050, 0.735, 299.4])
xdata.append([0.011, 1150, 0.735, 294.8])
xdata.append([0.011, 850, 0.735, 306.8])
xdata.append([0.011, 550,  0.945, 330.7])
xdata.append([0.011, 750, 0.945, 313.6])
xdata.append([0.011, 950, 0.944, 302.9])
xdata.append([0.011, 1150, 0.945, 295.6])
xdata.append([0.011, 850, 0.944, 307.7])
xdata.append([0.011, 700, 0.734, 324.7])
xdata.append([0.013, 550, 0.525, 342.2])
xdata.append([0.013, 750, 0.524,  322.3])
xdata.append([0.013, 950, 0.524, 310.0])
xdata.append([0.013, 1150, 0.525, 301.6])
xdata.append([0.013, 850, 0.524, 315.5])
xdata.append([0.013, 550, 0.734, 344.1])
xdata.append([0.013, 750, 0.735, 324.0])
xdata.append([0.013, 950, 0.735, 311.5])
xdata.append([0.013, 1050, 0.735, 306.3])
xdata.append([0.013, 1150, 0.735, 302.9])
xdata.append([0.013, 850, 0.734, 317.1])
xdata.append([0.013, 550, 0.945, 345.3])
xdata.append([0.013, 750, 0.944, 325.1])
xdata.append([0.013, 950, 0.944, 312.5])
xdata.append([0.013, 1150, 0.945, 303.9])
xdata.append([0.013, 850, 0.945, 318.2])


#data.append([mdot (kg/s)])

ydata.append([0.06157])
ydata.append([0.07269])
ydata.append([0.08396])
ydata.append([0.09347])
ydata.append([0.10635])
ydata.append([0.11521])
ydata.append([0.1287])
ydata.append([0.09516])
ydata.append([0.04398])
ydata.append([0.05997])
ydata.append([0.07596])
ydata.append([0.08343])
ydata.append([0.0919])
ydata.append([0.06797])
ydata.append([0.0342])
ydata.append([0.04664])
ydata.append([0.05908])
ydata.append([0.0715])
ydata.append([0.05286])
ydata.append([0.0846])
ydata.append([0.1154])
ydata.append([0.1462])
```

```
ydata.append([0.177])
ydata.append([0.1308])
ydata.append([0.06047])
ydata.append([0.08246])
ydata.append([0.1044])
ydata.append([0.1134])
ydata.append([0.1264])
ydata.append([0.0934])
ydata.append([0.047])
ydata.append([0.06413])
ydata.append([0.08124])
ydata.append([0.09834])
ydata.append([0.072691])
ydata.append([0.087196])
ydata.append([0.10005])
ydata.append([0.13644])
ydata.append([0.17282])
ydata.append([0.2092])
ydata.append([0.15463])
ydata.append([0.07147])
ydata.append([0.09745])
ydata.append([0.12344])
ydata.append([0.13302])
ydata.append([0.1494])
ydata.append([0.11045])
ydata.append([0.05558])
ydata.append([0.0758])
ydata.append([0.09601])
ydata.append([0.1162])
ydata.append([0.0859])

xarray3= numpy.array(xdata)
yarray3= numpy.array(ydata)
```

In [7]:

```
#Task 1.3a
import keras
import pandas as pd
from keras.models import Sequential
import numpy as np
import keras.backend as kb
import tensorflow as tf
import statistics as s
#the follwoing 2 lines are only needed for Mac OS machines
import os
os.environ['KMP_DUPLICATE_LIB_OK']='True'


Di3 =[] #inputs
q03 =[]
xe3 = []
Tw3 = []
mdot3 =[] #output
```

```
xarrayn3 = []
yarrayn3 = []

for x in range(len(xarray3)):
    Di3.append(xarray3[x][0])
    q03.append(xarray3[x][1])
    xe3.append(xarray3[x][2])
    Tw3.append(xarray3[x][3])

for y in range(len(yarray3)):
    mdot3.append(yarray3[y][0])

def median(sample):        #function to calculate median
    n = len(sample)
    i = n//2
    if n%2:
        return sorted (sample [i])
    return sum(sorted(sample)[i-1:i+1])/2

medDi3 = median(Di3)
medq03 = median(q03)
medxe3 = median(xe3)
medTw3 = median(Tw3)
medmdot3 = median(mdot3)

Din3 = Di3/medDi3
q0n3 = q03/medq03
xen3 = xe3/medxe3
Twn3 = Tw3/medTw3
mdotn3 = mdot3/medmdot3
xarrayn3 = np.column_stack((Din3, q0n3, xen3, Twn3))
yarrayn3 = mdotn3

print(xarrayn3)
print(yarrayn3)
```

```
[[0.72727273 0.64705882 0.71428571 1.00656383]
 [0.72727273 0.76470588 0.71428571 0.97965212]
 [0.72727273 0.88235294 0.71428571 0.96652445]
 [0.72727273 1.         0.71428571 0.95241221]
 [0.72727273 1.11764706 0.71292517 0.94158188]
 [0.72727273 1.23529412 0.71292517 0.93239252]
 [0.72727273 1.35294118 0.71428571 0.92451592]
 [0.72727273 1.         0.71292517 0.95277322]
 [0.72727273 0.64705882 0.99863946 1.01050213]
 [0.72727273 0.88235294 1.         0.96980637]
 [0.72727273 1.11764706 1.         0.94453561]
 [0.72727273 1.23529412 1.         0.93534624]
 [0.72727273 1.35294118 1.         0.92714145]
 [0.72727273 1.         0.99863946 0.95602232]
 [0.72727273 0.64705882 1.28571429 1.01279947]
 [0.72727273 0.88235294 1.28571429 0.97210371]
 [0.72727273 1.11764706 1.28571429 0.94683295]
```

```
 [0.72727273 1.35294118 1.28571429 0.9291106 ]
 [0.72727273 1.         1.28571429 0.95799147]
 [1.         0.64705882 0.71428571 1.07646866]
 [1.         0.88235294 0.71428571 1.02133246]
 [1.         1.11764706 0.71428571 0.98720053]
 [1.         1.35294118 0.71428571 0.96357073]
 [1.         1.         0.71428571 1.00262553]
 [1.         0.64705882 1.         1.08171972]
 [1.         0.88235294 1.         1.02592714]
 [1.         1.11764706 1.         0.99113883]
 [1.         1.23529412 1.         0.98260584]
 [1.         1.35294118 1.         0.96750903]
 [1.         1.         1.         1.00689202]
 [1.         0.64705882 1.28571429 1.08532983]
 [1.         0.88235294 1.28571429 1.02920906]
 [1.         1.11764706 1.28435374 0.99409255]
 [1.         1.35294118 1.28571429 0.97013456]
 [1.         1.         1.28435374 1.00984575]
 [1.         0.82352941 0.99863946 1.06563833]
 [1.18181818 0.64705882 0.71428571 1.12307187]
 [1.18181818 0.88235294 0.71292517 1.05776173]
 [1.18181818 1.11764706 0.71292517 1.01739416]
 [1.18181818 1.35294118 0.71428571 0.98982606]
 [1.18181818 1.         0.71292517 1.0354447 ]
 [1.18181818 0.64705882 0.99863946 1.12930752]
 [1.18181818 0.88235294 1.         1.06334099]
 [1.18181818 1.11764706 1.         1.02231703]
 [1.18181818 1.23529412 1.         1.00525107]
 [1.18181818 1.35294118 1.         0.99409255]
 [1.18181818 1.         0.99863946 1.04069577]
 [1.18181818 0.64705882 1.28571429 1.13324582]
 [1.18181818 0.88235294 1.28435374 1.0669511 ]
 [1.18181818 1.11764706 1.28435374 1.02559895]
 [1.18181818 1.35294118 1.28571429 0.99737447]
 [1.18181818 1.         1.28571429 1.04430587]]
[0.66454398 0.78456557 0.90620615 1.00885051 1.14786832 1.24349703
 1.38909876 1.0270912  0.47468969 0.64727469 0.81985969 0.9004857
 0.99190502 0.73362115 0.36913114 0.50339989 0.63766865 0.77172153
 0.57053427 0.91311387 1.24554776 1.57798165 1.91041554 1.41176471
 0.65267134 0.89001619 1.12682137 1.22396114 1.36427415 1.00809498
 0.50728548 0.69217485 0.87684835 1.06141392 0.78457636 0.9411333
 1.07987048 1.47263896 1.86529951 2.25796006 1.66896924 0.77139773
 1.05180788 1.33232596 1.43572585 1.61252024 1.19212089 0.59989207
 0.81813276 1.03626552 1.25418241 0.92714517]
```

In [7]:

```
#Task 1.3b
from sklearn.model_selection import train_test_split

X_train3, X_test3, y_train3, y_test3 = train_test_split(xarrayn3, yarrayn3, t

print(X_train3)
print(y_train3)
print(X_test3)
print(y_test3)
```

```
[[0.72727273 1.35294118 0.71428571 0.92451592]
```

```
[[0.72727273 1.35294118 0.71428571 0.92431592]
 [1.         1.         1.28435374 1.00984575]
 [0.72727273 1.11764706 0.71292517 0.94158188]
 [1.18181818 0.88235294 0.71292517 1.05776173]
 [1.         0.64705882 1.         1.08171972]
 [1.18181818 1.23529412 1.         1.00525107]
 [1.         1.35294118 1.28571429 0.97013456]
 [1.18181818 1.11764706 1.28435374 1.02559895]
 [0.72727273 0.88235294 1.28571429 0.97210371]
 [0.72727273 0.88235294 1.         0.96980637]
 [0.72727273 1.11764706 1.28571429 0.94683295]
 [1.         0.64705882 1.28571429 1.08532983]
 [1.18181818 0.64705882 0.71428571 1.12307187]
 [1.         0.88235294 1.         1.02592714]
 [0.72727273 1.23529412 1.         0.93534624]
 [0.72727273 0.64705882 0.71428571 1.00656383]
 [1.18181818 1.         0.99863946 1.04069577]
 [1.         1.23529412 1.         0.98260584]
 [1.         0.88235294 1.28571429 1.02920906]
 [1.18181818 1.35294118 0.71428571 0.98982606]
 [1.         1.         1.         1.00689202]
 [1.18181818 1.35294118 1.         0.99409255]
 [0.72727273 0.76470588 0.71428571 0.97965212]
 [1.         1.11764706 0.71428571 0.98720053]
 [0.72727273 0.88235294 0.71428571 0.96652445]
 [1.18181818 1.         0.71292517 1.0354447 ]
 [1.         0.82352941 0.99863946 1.06563833]
 [1.         1.         0.71428571 1.00262553]
 [1.18181818 0.88235294 1.28435374 1.0669511 ]
 [0.72727273 1.11764706 1.         0.94453561]
 [1.         1.35294118 0.71428571 0.96357073]
 [0.72727273 1.         1.28571429 0.95799147]
 [1.18181818 1.         1.28571429 1.04430587]
 [1.         0.88235294 0.71428571 1.02133246]
 [0.72727273 1.         0.71292517 0.95277322]
 [1.18181818 0.88235294 1.         1.06334099]
 [0.72727273 0.64705882 1.28571429 1.01279947]
 [1.         1.35294118 1.         0.96750903]
 [1.18181818 1.11764706 0.71292517 1.01739416]]
[1.38909876 0.78457636 1.14786832 1.47263896 0.65267134 1.43572585
 1.06141392 1.03626552 0.50339989 0.64727469 0.63766865 0.50728548
 1.07987048 0.89001619 0.9004857  0.66454398 1.19212089 1.22396114
 0.69217485 2.25796006 1.00809498 1.61252024 0.78456557 1.57798165
 0.90620615 1.66896924 0.9411333  1.41176471 0.81813276 0.81985969
 1.91041554 0.57053427 0.92714517 1.24554776 1.0270912  1.05180788
 0.36913114 1.36427415 1.86529951]
[[1.         0.64705882 0.71428571 1.07646866]
 [1.18181818 0.64705882 0.99863946 1.12930752]
 [1.18181818 0.64705882 1.28571429 1.13324582]
 [0.72727273 1.35294118 1.         0.92714145]
 [1.18181818 1.11764706 1.         1.02231703]
 [0.72727273 1.23529412 0.71292517 0.93239252]
 [0.72727273 1.35294118 1.28571429 0.9291106 ]
 [1.18181818 1.35294118 1.28571429 0.99737447]
 [0.72727273 1.         0.71428571 0.95241221]
 [1.         1.11764706 1.28435374 0.99409255]
 [0.72727273 1.         0.99863946 0.95602232]
```

```
 [0.72727273 0.64705882 0.99863946 1.01050213]
 [1.         1.11764706 1.         0.99113883]]
[0.91311387 0.77139773 0.59989207 0.99190502 1.33232596 1.24349703
 0.77172153 1.25418241 1.00885051 0.87684835 0.73362115 0.47468969
 1.12682137]
```

In [43]:

```
# define neural network model

from keras import backend as K
#initialize weights
initializer = keras.initializers.RandomUniform(minval= -0.2, maxval=0.5)

modelv3 = keras.Sequential([
    keras.layers.Dense(8, activation=K.elu, input_shape=[4],  kernel_initiali
    keras.layers.Dense(16, activation=K.elu,  kernel_initializer=initializer)
    keras.layers.Dense(16, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(16, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(1,  kernel_initializer=initializer)
  ])
```

In [47]:

```
#from tf.keras import optimizers
rms = keras.optimizers.RMSprop(0.001)
modelv3.compile(loss='mean_absolute_error',optimizer=rms)
```

In [48]:

```
# Add an early stopping callback
es = keras.callbacks.EarlyStopping(
    monitor='loss',
    mode='min',
    patience = 80,
    restore_best_weights = True,
    verbose=1)
# Add a checkpoint where loss is minimum, and save that model
mc = keras.callbacks.ModelCheckpoint('best_modelv3.SB', monitor='loss',
                     mode='min',  verbose=1, save_best_only=True)

historyData3 = modelv3.fit(X_train3,y_train3,epochs=800,callbacks=[es])

loss_hist3 = historyData3.history['loss']
#The above line will return a dictionary, access it's info like this:
best_epoch3 = np.argmin(historyData3.history['loss']) + 1
print ('best epoch = ', best_epoch3)
print('smallest loss =', np.min(loss_hist3))

modelv3.save('./best_modelv3')
```

```
Epoch 1/800
39/39 [==============================] - 1s 37ms/step - loss: 0.0490
Epoch 2/800
39/39 [==============================] - 0s 607us/step - loss: 0.0431
Epoch 3/800
```

```
39/39 [==============================] - 0s 758us/step - loss: 0.0441
Epoch 4/800
39/39 [==============================] - 0s 2ms/step - loss: 0.0455
Epoch 5/800
39/39 [==============================] - 0s 462us/step - loss: 0.0472
Epoch 6/800
39/39 [==============================] - 0s 462us/step - loss: 0.0353
Epoch 7/800
39/39 [==============================] - 0s 995us/step - loss: 0.0497
Epoch 8/800
39/39 [==============================] - 0s 547us/step - loss: 0.0385
Epoch 9/800
39/39 [==============================] - 0s 877us/step - loss: 0.0361
Epoch 10/800
39/39 [==============================] - 0s 682us/step - loss: 0.0441
Epoch 11/800
39/39 [==============================] - 0s 559us/step - loss: 0.0401
Epoch 12/800
39/39 [==============================] - 0s 427us/step - loss: 0.0639
Epoch 13/800
39/39 [==============================] - 0s 418us/step - loss: 0.0375
Epoch 14/800
39/39 [==============================] - 0s 302us/step - loss: 0.0471
Epoch 15/800
39/39 [==============================] - 0s 320us/step - loss: 0.0423
Epoch 16/800
39/39 [==============================] - 0s 274us/step - loss: 0.0392
Epoch 17/800
39/39 [==============================] - 0s 246us/step - loss: 0.0476
Epoch 18/800
39/39 [==============================] - 0s 348us/step - loss: 0.0343
Epoch 19/800
39/39 [==============================] - 0s 416us/step - loss: 0.0351
Epoch 20/800
39/39 [==============================] - 0s 349us/step - loss: 0.0426
Epoch 21/800
39/39 [==============================] - 0s 298us/step - loss: 0.0493
Epoch 22/800
39/39 [==============================] - 0s 309us/step - loss: 0.0368
Epoch 23/800
39/39 [==============================] - 0s 275us/step - loss: 0.0459
Epoch 24/800
39/39 [==============================] - 0s 270us/step - loss: 0.0341
Epoch 25/800
39/39 [==============================] - 0s 285us/step - loss: 0.0386
Epoch 26/800
39/39 [==============================] - 0s 586us/step - loss: 0.0379
Epoch 27/800
39/39 [==============================] - 0s 511us/step - loss: 0.0354
Epoch 28/800
39/39 [==============================] - 0s 329us/step - loss: 0.0398
Epoch 29/800
39/39 [==============================] - 0s 295us/step - loss: 0.0368
Epoch 30/800
39/39 [==============================] - 0s 292us/step - loss: 0.0374
Epoch 31/800
39/39 [==============================] - 0s 297us/step - loss: 0.0338
```

```
Epoch 32/800
39/39 [==============================] - 0s 329us/step - loss: 0.0424
Epoch 33/800
39/39 [==============================] - 0s 581us/step - loss: 0.0437
Epoch 34/800
39/39 [==============================] - 0s 296us/step - loss: 0.0332
Epoch 35/800
39/39 [==============================] - 0s 315us/step - loss: 0.0559
Epoch 36/800
39/39 [==============================] - 0s 577us/step - loss: 0.0354
Epoch 37/800
39/39 [==============================] - 0s 296us/step - loss: 0.0513
Epoch 38/800
39/39 [==============================] - 0s 368us/step - loss: 0.0356
Epoch 39/800
39/39 [==============================] - 0s 380us/step - loss: 0.0354
Epoch 40/800
39/39 [==============================] - 0s 389us/step - loss: 0.0332
Epoch 41/800
39/39 [==============================] - 0s 317us/step - loss: 0.0338
Epoch 42/800
39/39 [==============================] - 0s 394us/step - loss: 0.0340
Epoch 43/800
39/39 [==============================] - 0s 458us/step - loss: 0.0666
Epoch 44/800
39/39 [==============================] - 0s 422us/step - loss: 0.0354
Epoch 45/800
39/39 [==============================] - 0s 409us/step - loss: 0.0366
Epoch 46/800
39/39 [==============================] - 0s 328us/step - loss: 0.0420
Epoch 47/800
39/39 [==============================] - 0s 540us/step - loss: 0.0380
Epoch 48/800
39/39 [==============================] - 0s 296us/step - loss: 0.0509
Epoch 49/800
39/39 [==============================] - 0s 357us/step - loss: 0.0543
Epoch 50/800
39/39 [==============================] - 0s 412us/step - loss: 0.0421
Epoch 51/800
39/39 [==============================] - 0s 321us/step - loss: 0.0444
Epoch 52/800
39/39 [==============================] - 0s 432us/step - loss: 0.0355
Epoch 53/800
39/39 [==============================] - 0s 457us/step - loss: 0.0372
Epoch 54/800
39/39 [==============================] - 0s 280us/step - loss: 0.0339
Epoch 55/800
39/39 [==============================] - 0s 292us/step - loss: 0.0376
Epoch 56/800
39/39 [==============================] - 0s 301us/step - loss: 0.0323
Epoch 57/800
39/39 [==============================] - 0s 216us/step - loss: 0.0358
Epoch 58/800
39/39 [==============================] - 0s 250us/step - loss: 0.0363
Epoch 59/800
39/39 [==============================] - 0s 241us/step - loss: 0.0323
Epoch 60/800
```

```
39/39 [==============================] - 0s 290us/step - loss: 0.0413
Epoch 61/800
39/39 [==============================] - 0s 363us/step - loss: 0.0447
Epoch 62/800
39/39 [==============================] - 0s 391us/step - loss: 0.0533
Epoch 63/800
39/39 [==============================] - 0s 333us/step - loss: 0.0322
Epoch 64/800
39/39 [==============================] - 0s 318us/step - loss: 0.0540
Epoch 65/800
39/39 [==============================] - 0s 337us/step - loss: 0.0456
Epoch 66/800
39/39 [==============================] - 0s 333us/step - loss: 0.0491
Epoch 67/800
39/39 [==============================] - 0s 334us/step - loss: 0.0336
Epoch 68/800
39/39 [==============================] - 0s 419us/step - loss: 0.0329
Epoch 69/800
39/39 [==============================] - 0s 285us/step - loss: 0.0314
Epoch 70/800
39/39 [==============================] - 0s 396us/step - loss: 0.0405
Epoch 71/800
39/39 [==============================] - 0s 518us/step - loss: 0.0372
Epoch 72/800
39/39 [==============================] - 0s 355us/step - loss: 0.0363
Epoch 73/800
39/39 [==============================] - 0s 405us/step - loss: 0.0387
Epoch 74/800
39/39 [==============================] - 0s 497us/step - loss: 0.0358
Epoch 75/800
39/39 [==============================] - 0s 727us/step - loss: 0.0333
Epoch 76/800
39/39 [==============================] - 0s 486us/step - loss: 0.0527
Epoch 77/800
39/39 [==============================] - 0s 452us/step - loss: 0.0552
Epoch 78/800
39/39 [==============================] - 0s 430us/step - loss: 0.0533
Epoch 79/800
39/39 [==============================] - 0s 362us/step - loss: 0.0369
Epoch 80/800
39/39 [==============================] - 0s 283us/step - loss: 0.0313
Epoch 81/800
39/39 [==============================] - 0s 382us/step - loss: 0.0365
Epoch 82/800
39/39 [==============================] - 0s 591us/step - loss: 0.0439
Epoch 83/800
39/39 [==============================] - 0s 379us/step - loss: 0.0329
Epoch 84/800
39/39 [==============================] - 0s 593us/step - loss: 0.0303
Epoch 85/800
39/39 [==============================] - 0s 291us/step - loss: 0.0390
Epoch 86/800
39/39 [==============================] - 0s 438us/step - loss: 0.0317
Epoch 87/800
39/39 [==============================] - 0s 498us/step - loss: 0.0312
Epoch 88/800
39/39 [==============================] - 0s 332us/step - loss: 0.0324
```

```
Epoch 89/800
39/39 [==============================] - 0s 373us/step - loss: 0.0442
Epoch 90/800
39/39 [==============================] - 0s 366us/step - loss: 0.0523
Epoch 91/800
39/39 [==============================] - 0s 392us/step - loss: 0.0342
Epoch 92/800
39/39 [==============================] - 0s 303us/step - loss: 0.0307
Epoch 93/800
39/39 [==============================] - 0s 467us/step - loss: 0.0308
Epoch 94/800
39/39 [==============================] - 0s 476us/step - loss: 0.0487
Epoch 95/800
39/39 [==============================] - 0s 325us/step - loss: 0.0367
Epoch 96/800
39/39 [==============================] - 0s 422us/step - loss: 0.0339
Epoch 97/800
39/39 [==============================] - 0s 346us/step - loss: 0.0348
Epoch 98/800
39/39 [==============================] - 0s 776us/step - loss: 0.0411
Epoch 99/800
39/39 [==============================] - 0s 595us/step - loss: 0.0729
Epoch 100/800
39/39 [==============================] - 0s 464us/step - loss: 0.0306
Epoch 101/800
39/39 [==============================] - 0s 917us/step - loss: 0.0340
Epoch 102/800
39/39 [==============================] - 0s 515us/step - loss: 0.0315
Epoch 103/800
39/39 [==============================] - 0s 558us/step - loss: 0.0310
Epoch 104/800
39/39 [==============================] - 0s 635us/step - loss: 0.0317
Epoch 105/800
39/39 [==============================] - 0s 450us/step - loss: 0.0581
Epoch 106/800
39/39 [==============================] - 0s 493us/step - loss: 0.0333
Epoch 107/800
39/39 [==============================] - 0s 522us/step - loss: 0.0386
Epoch 108/800
39/39 [==============================] - 0s 441us/step - loss: 0.0296
Epoch 109/800
39/39 [==============================] - 0s 445us/step - loss: 0.0450
Epoch 110/800
39/39 [==============================] - 0s 406us/step - loss: 0.0361
Epoch 111/800
39/39 [==============================] - 0s 466us/step - loss: 0.0416
Epoch 112/800
39/39 [==============================] - 0s 370us/step - loss: 0.0415
Epoch 113/800
39/39 [==============================] - 0s 366us/step - loss: 0.0349
Epoch 114/800
39/39 [==============================] - 0s 414us/step - loss: 0.0316
Epoch 115/800
39/39 [==============================] - 0s 434us/step - loss: 0.0341
Epoch 116/800
39/39 [==============================] - 0s 387us/step - loss: 0.0302
Epoch 117/800
```

```
39/39 [==============================] - 0s 362us/step - loss: 0.0566
Epoch 118/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0296
Epoch 119/800
39/39 [==============================] - 0s 521us/step - loss: 0.0478
Epoch 120/800
39/39 [==============================] - 0s 509us/step - loss: 0.0357
Epoch 121/800
39/39 [==============================] - 0s 370us/step - loss: 0.0413
Epoch 122/800
39/39 [==============================] - 0s 380us/step - loss: 0.0296
Epoch 123/800
39/39 [==============================] - 0s 578us/step - loss: 0.0521
Epoch 124/800
39/39 [==============================] - 0s 440us/step - loss: 0.0311
Epoch 125/800
39/39 [==============================] - 0s 274us/step - loss: 0.0379
Epoch 126/800
39/39 [==============================] - 0s 417us/step - loss: 0.0302
Epoch 127/800
39/39 [==============================] - 0s 396us/step - loss: 0.0383
Epoch 128/800
39/39 [==============================] - 0s 335us/step - loss: 0.0438
Epoch 129/800
39/39 [==============================] - 0s 389us/step - loss: 0.0321
Epoch 130/800
39/39 [==============================] - 0s 449us/step - loss: 0.0293
Epoch 131/800
39/39 [==============================] - 0s 358us/step - loss: 0.0362
Epoch 132/800
39/39 [==============================] - 0s 434us/step - loss: 0.0434
Epoch 133/800
39/39 [==============================] - 0s 663us/step - loss: 0.0479
Epoch 134/800
39/39 [==============================] - 0s 681us/step - loss: 0.0315
Epoch 135/800
39/39 [==============================] - 0s 331us/step - loss: 0.0290
Epoch 136/800
39/39 [==============================] - 0s 260us/step - loss: 0.0366
Epoch 137/800
39/39 [==============================] - 0s 317us/step - loss: 0.0341
Epoch 138/800
39/39 [==============================] - 0s 285us/step - loss: 0.0388
Epoch 139/800
39/39 [==============================] - 0s 357us/step - loss: 0.0504
Epoch 140/800
39/39 [==============================] - 0s 390us/step - loss: 0.0307
Epoch 141/800
39/39 [==============================] - 0s 348us/step - loss: 0.0304
Epoch 142/800
39/39 [==============================] - 0s 292us/step - loss: 0.0318
Epoch 143/800
39/39 [==============================] - 0s 302us/step - loss: 0.0308
Epoch 144/800
39/39 [==============================] - 0s 388us/step - loss: 0.0328
Epoch 145/800
39/39 [==============================] - 0s 259us/step - loss: 0.0316
```

```
Epoch 146/800
39/39 [==============================] - 0s 280us/step - loss: 0.0299
Epoch 147/800
39/39 [==============================] - 0s 286us/step - loss: 0.0333
Epoch 148/800
39/39 [==============================] - 0s 284us/step - loss: 0.0607
Epoch 149/800
39/39 [==============================] - 0s 434us/step - loss: 0.0325
Epoch 150/800
39/39 [==============================] - 0s 303us/step - loss: 0.0377
Epoch 151/800
39/39 [==============================] - 0s 303us/step - loss: 0.0339
Epoch 152/800
39/39 [==============================] - 0s 335us/step - loss: 0.0324
Epoch 153/800
39/39 [==============================] - 0s 365us/step - loss: 0.0287
Epoch 154/800
39/39 [==============================] - 0s 250us/step - loss: 0.0426
Epoch 155/800
39/39 [==============================] - 0s 304us/step - loss: 0.0467
Epoch 156/800
39/39 [==============================] - 0s 280us/step - loss: 0.0448
Epoch 157/800
39/39 [==============================] - 0s 408us/step - loss: 0.0369
Epoch 158/800
39/39 [==============================] - 0s 410us/step - loss: 0.0279
Epoch 159/800
39/39 [==============================] - 0s 261us/step - loss: 0.0295
Epoch 160/800
39/39 [==============================] - 0s 307us/step - loss: 0.0291
Epoch 161/800
39/39 [==============================] - 0s 275us/step - loss: 0.0296
Epoch 162/800
39/39 [==============================] - 0s 279us/step - loss: 0.0421
Epoch 163/800
39/39 [==============================] - 0s 284us/step - loss: 0.0607
Epoch 164/800
39/39 [==============================] - 0s 417us/step - loss: 0.0394
Epoch 165/800
39/39 [==============================] - 0s 324us/step - loss: 0.0439
Epoch 166/800
39/39 [==============================] - 0s 272us/step - loss: 0.0304
Epoch 167/800
39/39 [==============================] - 0s 247us/step - loss: 0.0307
Epoch 168/800
39/39 [==============================] - 0s 275us/step - loss: 0.0406
Epoch 169/800
39/39 [==============================] - 0s 249us/step - loss: 0.0447
Epoch 170/800
39/39 [==============================] - 0s 281us/step - loss: 0.0436
Epoch 171/800
39/39 [==============================] - 0s 324us/step - loss: 0.0283
Epoch 172/800
39/39 [==============================] - 0s 283us/step - loss: 0.0311
Epoch 173/800
39/39 [==============================] - 0s 317us/step - loss: 0.0513
Epoch 174/800
```

```
39/39 [==============================] - 0s 334us/step - loss: 0.0278
Epoch 175/800
39/39 [==============================] - 0s 329us/step - loss: 0.0302
Epoch 176/800
39/39 [==============================] - 0s 613us/step - loss: 0.0340
Epoch 177/800
39/39 [==============================] - 0s 383us/step - loss: 0.0342
Epoch 178/800
39/39 [==============================] - 0s 363us/step - loss: 0.0434
Epoch 179/800
39/39 [==============================] - 0s 403us/step - loss: 0.0332
Epoch 180/800
39/39 [==============================] - 0s 469us/step - loss: 0.0471
Epoch 181/800
39/39 [==============================] - 0s 427us/step - loss: 0.0278
Epoch 182/800
39/39 [==============================] - 0s 422us/step - loss: 0.0386
Epoch 183/800
39/39 [==============================] - 0s 333us/step - loss: 0.0336
Epoch 184/800
39/39 [==============================] - 0s 475us/step - loss: 0.0415
Epoch 185/800
39/39 [==============================] - 0s 353us/step - loss: 0.0286
Epoch 186/800
39/39 [==============================] - 0s 336us/step - loss: 0.0434
Epoch 187/800
39/39 [==============================] - 0s 306us/step - loss: 0.0376
Epoch 188/800
39/39 [==============================] - 0s 425us/step - loss: 0.0347
Epoch 189/800
39/39 [==============================] - 0s 395us/step - loss: 0.0306
Epoch 190/800
39/39 [==============================] - 0s 343us/step - loss: 0.0353
Epoch 191/800
39/39 [==============================] - 0s 373us/step - loss: 0.0320
Epoch 192/800
39/39 [==============================] - 0s 369us/step - loss: 0.0284
Epoch 193/800
39/39 [==============================] - 0s 330us/step - loss: 0.0344
Epoch 194/800
39/39 [==============================] - 0s 364us/step - loss: 0.0342
Epoch 195/800
39/39 [==============================] - 0s 371us/step - loss: 0.0301
Epoch 196/800
39/39 [==============================] - 0s 321us/step - loss: 0.0273
Epoch 197/800
39/39 [==============================] - 0s 291us/step - loss: 0.0361
Epoch 198/800
39/39 [==============================] - 0s 398us/step - loss: 0.0388
Epoch 199/800
39/39 [==============================] - 0s 303us/step - loss: 0.0313
Epoch 200/800
39/39 [==============================] - 0s 286us/step - loss: 0.0479
Epoch 201/800
39/39 [==============================] - 0s 333us/step - loss: 0.0284
Epoch 202/800
39/39 [==============================] - 0s 267us/step - loss: 0.0498
```

```
Epoch 203/800
39/39 [==============================] - 0s 380us/step - loss: 0.0381
Epoch 204/800
39/39 [==============================] - 0s 400us/step - loss: 0.0464
Epoch 205/800
39/39 [==============================] - 0s 341us/step - loss: 0.0327
Epoch 206/800
39/39 [==============================] - 0s 362us/step - loss: 0.0328
Epoch 207/800
39/39 [==============================] - 0s 370us/step - loss: 0.0442
Epoch 208/800
39/39 [==============================] - 0s 356us/step - loss: 0.0402
Epoch 209/800
39/39 [==============================] - 0s 399us/step - loss: 0.0263
Epoch 210/800
39/39 [==============================] - 0s 634us/step - loss: 0.0442
Epoch 211/800
39/39 [==============================] - 0s 350us/step - loss: 0.0306
Epoch 212/800
39/39 [==============================] - 0s 419us/step - loss: 0.0281
Epoch 213/800
39/39 [==============================] - 0s 434us/step - loss: 0.0310
Epoch 214/800
39/39 [==============================] - 0s 338us/step - loss: 0.0391
Epoch 215/800
39/39 [==============================] - 0s 299us/step - loss: 0.0441
Epoch 216/800
39/39 [==============================] - 0s 362us/step - loss: 0.0344
Epoch 217/800
39/39 [==============================] - 0s 290us/step - loss: 0.0425
Epoch 218/800
39/39 [==============================] - 0s 427us/step - loss: 0.0315
Epoch 219/800
39/39 [==============================] - 0s 311us/step - loss: 0.0345
Epoch 220/800
39/39 [==============================] - 0s 295us/step - loss: 0.0399
Epoch 221/800
39/39 [==============================] - 0s 337us/step - loss: 0.0415
Epoch 222/800
39/39 [==============================] - 0s 317us/step - loss: 0.0308
Epoch 223/800
39/39 [==============================] - 0s 485us/step - loss: 0.0401
Epoch 224/800
39/39 [==============================] - 0s 420us/step - loss: 0.0334
Epoch 225/800
39/39 [==============================] - 0s 343us/step - loss: 0.0276
Epoch 226/800
39/39 [==============================] - 0s 414us/step - loss: 0.0451
Epoch 227/800
39/39 [==============================] - 0s 453us/step - loss: 0.0417
Epoch 228/800
39/39 [==============================] - 0s 445us/step - loss: 0.0355
Epoch 229/800
39/39 [==============================] - 0s 442us/step - loss: 0.0396
Epoch 230/800
39/39 [==============================] - 0s 472us/step - loss: 0.0266
Epoch 231/800
```

```
39/39 [==============================] - 0s 501us/step - loss: 0.0446
Epoch 232/800
39/39 [==============================] - 0s 516us/step - loss: 0.0273
Epoch 233/800
39/39 [==============================] - 0s 505us/step - loss: 0.0408
Epoch 234/800
39/39 [==============================] - 0s 326us/step - loss: 0.0338
Epoch 235/800
39/39 [==============================] - 0s 527us/step - loss: 0.0433
Epoch 236/800
39/39 [==============================] - 0s 470us/step - loss: 0.0267
Epoch 237/800
39/39 [==============================] - 0s 428us/step - loss: 0.0259
Epoch 238/800
39/39 [==============================] - 0s 398us/step - loss: 0.0361
Epoch 239/800
39/39 [==============================] - 0s 851us/step - loss: 0.0271
Epoch 240/800
39/39 [==============================] - 0s 513us/step - loss: 0.0452
Epoch 241/800
39/39 [==============================] - 0s 480us/step - loss: 0.0377
Epoch 242/800
39/39 [==============================] - 0s 376us/step - loss: 0.0358
Epoch 243/800
39/39 [==============================] - 0s 328us/step - loss: 0.0318
Epoch 244/800
39/39 [==============================] - 0s 343us/step - loss: 0.0435
Epoch 245/800
39/39 [==============================] - 0s 660us/step - loss: 0.0277
Epoch 246/800
39/39 [==============================] - 0s 314us/step - loss: 0.0374
Epoch 247/800
39/39 [==============================] - 0s 349us/step - loss: 0.0369
Epoch 248/800
39/39 [==============================] - 0s 272us/step - loss: 0.0302
Epoch 249/800
39/39 [==============================] - 0s 441us/step - loss: 0.0368
Epoch 250/800
39/39 [==============================] - 0s 484us/step - loss: 0.0396
Epoch 251/800
39/39 [==============================] - 0s 774us/step - loss: 0.0290
Epoch 252/800
39/39 [==============================] - 0s 637us/step - loss: 0.0266
Epoch 253/800
39/39 [==============================] - 0s 694us/step - loss: 0.0268
Epoch 254/800
39/39 [==============================] - 0s 909us/step - loss: 0.0276
Epoch 255/800
39/39 [==============================] - 0s 514us/step - loss: 0.0436
Epoch 256/800
39/39 [==============================] - 0s 321us/step - loss: 0.0286
Epoch 257/800
39/39 [==============================] - 0s 349us/step - loss: 0.0444
Epoch 258/800
39/39 [==============================] - 0s 358us/step - loss: 0.0470
Epoch 259/800
39/39 [==============================] - 0s 433us/step - loss: 0.0348
```

```
Epoch 260/800
39/39 [==============================] - 0s 335us/step - loss: 0.0279
Epoch 261/800
39/39 [==============================] - 0s 346us/step - loss: 0.0421
Epoch 262/800
39/39 [==============================] - 0s 301us/step - loss: 0.0262
Epoch 263/800
39/39 [==============================] - 0s 372us/step - loss: 0.0291
Epoch 264/800
39/39 [==============================] - 0s 307us/step - loss: 0.0387
Epoch 265/800
39/39 [==============================] - 0s 484us/step - loss: 0.0489
Epoch 266/800
39/39 [==============================] - 0s 349us/step - loss: 0.0303
Epoch 267/800
39/39 [==============================] - 0s 465us/step - loss: 0.0263
Epoch 268/800
39/39 [==============================] - 0s 403us/step - loss: 0.0253
Epoch 269/800
39/39 [==============================] - 0s 417us/step - loss: 0.0322
Epoch 270/800
39/39 [==============================] - 0s 406us/step - loss: 0.0257
Epoch 271/800
39/39 [==============================] - 0s 325us/step - loss: 0.0338
Epoch 272/800
39/39 [==============================] - 0s 363us/step - loss: 0.0384
Epoch 273/800
39/39 [==============================] - 0s 325us/step - loss: 0.0426
Epoch 274/800
39/39 [==============================] - 0s 493us/step - loss: 0.0254
Epoch 275/800
39/39 [==============================] - 0s 326us/step - loss: 0.0424
Epoch 276/800
39/39 [==============================] - 0s 305us/step - loss: 0.0483
Epoch 277/800
39/39 [==============================] - 0s 370us/step - loss: 0.0284
Epoch 278/800
39/39 [==============================] - 0s 356us/step - loss: 0.0312
Epoch 279/800
39/39 [==============================] - 0s 394us/step - loss: 0.0373
Epoch 280/800
39/39 [==============================] - 0s 371us/step - loss: 0.0486
Epoch 281/800
39/39 [==============================] - 0s 299us/step - loss: 0.0384
Epoch 282/800
39/39 [==============================] - 0s 284us/step - loss: 0.0392
Epoch 283/800
39/39 [==============================] - 0s 359us/step - loss: 0.0365
Epoch 284/800
39/39 [==============================] - 0s 492us/step - loss: 0.0268
Epoch 285/800
39/39 [==============================] - 0s 328us/step - loss: 0.0314
Epoch 286/800
39/39 [==============================] - 0s 419us/step - loss: 0.0276
Epoch 287/800
39/39 [==============================] - 0s 622us/step - loss: 0.0285
Epoch 288/800
```

```
39/39 [==============================] - 0s 748us/step - loss: 0.0350
Epoch 289/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0299
Epoch 290/800
39/39 [==============================] - 0s 663us/step - loss: 0.0279
Epoch 291/800
39/39 [==============================] - 0s 444us/step - loss: 0.0267
Epoch 292/800
39/39 [==============================] - 0s 629us/step - loss: 0.0323
Epoch 293/800
39/39 [==============================] - 0s 373us/step - loss: 0.0388
Epoch 294/800
39/39 [==============================] - 0s 387us/step - loss: 0.0298
Epoch 295/800
39/39 [==============================] - 0s 531us/step - loss: 0.0426
Epoch 296/800
39/39 [==============================] - 0s 629us/step - loss: 0.0300
Epoch 297/800
39/39 [==============================] - 0s 306us/step - loss: 0.0385
Epoch 298/800
39/39 [==============================] - 0s 284us/step - loss: 0.0354
Epoch 299/800
39/39 [==============================] - 0s 645us/step - loss: 0.0277
Epoch 300/800
39/39 [==============================] - 0s 425us/step - loss: 0.0323
Epoch 301/800
39/39 [==============================] - 0s 459us/step - loss: 0.0328
Epoch 302/800
39/39 [==============================] - 0s 391us/step - loss: 0.0257
Epoch 303/800
39/39 [==============================] - 0s 417us/step - loss: 0.0308
Epoch 304/800
39/39 [==============================] - 0s 518us/step - loss: 0.0273
Epoch 305/800
39/39 [==============================] - 0s 307us/step - loss: 0.0287
Epoch 306/800
39/39 [==============================] - 0s 331us/step - loss: 0.0394
Epoch 307/800
39/39 [==============================] - 0s 633us/step - loss: 0.0385
Epoch 308/800
39/39 [==============================] - 0s 585us/step - loss: 0.0353
Epoch 309/800
39/39 [==============================] - 0s 814us/step - loss: 0.0317
Epoch 310/800
39/39 [==============================] - 0s 585us/step - loss: 0.0285
Epoch 311/800
39/39 [==============================] - 0s 480us/step - loss: 0.0253
Epoch 312/800
39/39 [==============================] - 0s 288us/step - loss: 0.0279
Epoch 313/800
39/39 [==============================] - 0s 296us/step - loss: 0.0275
Epoch 314/800
39/39 [==============================] - 0s 377us/step - loss: 0.0332
Epoch 315/800
39/39 [==============================] - 0s 401us/step - loss: 0.0265
Epoch 316/800
39/39 [==============================] - 0s 376us/step - loss: 0.0379
```

```
Epoch 317/800
39/39 [==============================] - 0s 298us/step - loss: 0.0384
Epoch 318/800
39/39 [==============================] - 0s 323us/step - loss: 0.0414
Epoch 319/800
39/39 [==============================] - 0s 391us/step - loss: 0.0400
Epoch 320/800
39/39 [==============================] - 0s 278us/step - loss: 0.0314
Epoch 321/800
39/39 [==============================] - 0s 330us/step - loss: 0.0307
Epoch 322/800
39/39 [==============================] - 0s 395us/step - loss: 0.0322
Epoch 323/800
39/39 [==============================] - 0s 451us/step - loss: 0.0260
Epoch 324/800
39/39 [==============================] - 0s 486us/step - loss: 0.0332
Epoch 325/800
39/39 [==============================] - 0s 421us/step - loss: 0.0247
Epoch 326/800
39/39 [==============================] - 0s 350us/step - loss: 0.0386
Epoch 327/800
39/39 [==============================] - 0s 320us/step - loss: 0.0309
Epoch 328/800
39/39 [==============================] - 0s 509us/step - loss: 0.0369
Epoch 329/800
39/39 [==============================] - 0s 311us/step - loss: 0.0299
Epoch 330/800
39/39 [==============================] - 0s 456us/step - loss: 0.0275
Epoch 331/800
39/39 [==============================] - 0s 396us/step - loss: 0.0412
Epoch 332/800
39/39 [==============================] - 0s 427us/step - loss: 0.0259
Epoch 333/800
39/39 [==============================] - 0s 570us/step - loss: 0.0298
Epoch 334/800
39/39 [==============================] - 0s 312us/step - loss: 0.0297
Epoch 335/800
39/39 [==============================] - 0s 308us/step - loss: 0.0307
Epoch 336/800
39/39 [==============================] - 0s 441us/step - loss: 0.0473
Epoch 337/800
39/39 [==============================] - 0s 503us/step - loss: 0.0252
Epoch 338/800
39/39 [==============================] - 0s 397us/step - loss: 0.0265
Epoch 339/800
39/39 [==============================] - 0s 393us/step - loss: 0.0310
Epoch 340/800
39/39 [==============================] - 0s 372us/step - loss: 0.0313
Epoch 341/800
39/39 [==============================] - 0s 289us/step - loss: 0.0255
Epoch 342/800
39/39 [==============================] - 0s 340us/step - loss: 0.0295
Epoch 343/800
39/39 [==============================] - 0s 395us/step - loss: 0.0488
Epoch 344/800
39/39 [==============================] - 0s 710us/step - loss: 0.0528
Epoch 345/800
```

```
39/39 [==============================] - 0s 312us/step - loss: 0.0293
Epoch 346/800
39/39 [==============================] - 0s 409us/step - loss: 0.0260
Epoch 347/800
39/39 [==============================] - 0s 356us/step - loss: 0.0277
Epoch 348/800
39/39 [==============================] - 0s 304us/step - loss: 0.0281
Epoch 349/800
39/39 [==============================] - 0s 342us/step - loss: 0.0282
Epoch 350/800
39/39 [==============================] - 0s 346us/step - loss: 0.0298
Epoch 351/800
39/39 [==============================] - 0s 760us/step - loss: 0.0315
Epoch 352/800
39/39 [==============================] - 0s 937us/step - loss: 0.0457
Epoch 353/800
39/39 [==============================] - 0s 817us/step - loss: 0.0258
Epoch 354/800
39/39 [==============================] - 0s 637us/step - loss: 0.0297
Epoch 355/800
39/39 [==============================] - 0s 404us/step - loss: 0.0336
Epoch 356/800
39/39 [==============================] - 0s 556us/step - loss: 0.0313
Epoch 357/800
39/39 [==============================] - 0s 585us/step - loss: 0.0245
Epoch 358/800
39/39 [==============================] - 0s 466us/step - loss: 0.0280
Epoch 359/800
39/39 [==============================] - 0s 515us/step - loss: 0.0512
Epoch 360/800
39/39 [==============================] - 0s 546us/step - loss: 0.0307
Epoch 361/800
39/39 [==============================] - 0s 497us/step - loss: 0.0277
Epoch 362/800
39/39 [==============================] - 0s 310us/step - loss: 0.0368
Epoch 363/800
39/39 [==============================] - 0s 361us/step - loss: 0.0402
Epoch 364/800
39/39 [==============================] - 0s 448us/step - loss: 0.0259
Epoch 365/800
39/39 [==============================] - 0s 456us/step - loss: 0.0355
Epoch 366/800
39/39 [==============================] - 0s 404us/step - loss: 0.0410
Epoch 367/800
39/39 [==============================] - 0s 325us/step - loss: 0.0475
Epoch 368/800
39/39 [==============================] - 0s 329us/step - loss: 0.0373
Epoch 369/800
39/39 [==============================] - 0s 399us/step - loss: 0.0281
Epoch 370/800
39/39 [==============================] - 0s 403us/step - loss: 0.0333
Epoch 371/800
39/39 [==============================] - 0s 363us/step - loss: 0.0348
Epoch 372/800
39/39 [==============================] - 0s 486us/step - loss: 0.0322
Epoch 373/800
39/39 [==============================] - 0s 272us/step - loss: 0.0421
```

```
Epoch 374/800
39/39 [==============================] - 0s 362us/step - loss: 0.0273
Epoch 375/800
39/39 [==============================] - 0s 343us/step - loss: 0.0239
Epoch 376/800
39/39 [==============================] - 0s 410us/step - loss: 0.0288
Epoch 377/800
39/39 [==============================] - 0s 391us/step - loss: 0.0570
Epoch 378/800
39/39 [==============================] - 0s 320us/step - loss: 0.0287
Epoch 379/800
39/39 [==============================] - 0s 469us/step - loss: 0.0362
Epoch 380/800
39/39 [==============================] - 0s 758us/step - loss: 0.0364
Epoch 381/800
39/39 [==============================] - 0s 433us/step - loss: 0.0279
Epoch 382/800
39/39 [==============================] - 0s 476us/step - loss: 0.0453
Epoch 383/800
39/39 [==============================] - 0s 310us/step - loss: 0.0335
Epoch 384/800
39/39 [==============================] - 0s 410us/step - loss: 0.0359
Epoch 385/800
39/39 [==============================] - 0s 373us/step - loss: 0.0245
Epoch 386/800
39/39 [==============================] - 0s 392us/step - loss: 0.0328
Epoch 387/800
39/39 [==============================] - 0s 397us/step - loss: 0.0242
Epoch 388/800
39/39 [==============================] - 0s 333us/step - loss: 0.0409
Epoch 389/800
39/39 [==============================] - 0s 405us/step - loss: 0.0312
Epoch 390/800
39/39 [==============================] - 0s 411us/step - loss: 0.0251
Epoch 391/800
39/39 [==============================] - 0s 612us/step - loss: 0.0250
Epoch 392/800
39/39 [==============================] - 0s 324us/step - loss: 0.0253
Epoch 393/800
39/39 [==============================] - 0s 368us/step - loss: 0.0286
Epoch 394/800
39/39 [==============================] - 0s 348us/step - loss: 0.0346
Epoch 395/800
39/39 [==============================] - 0s 627us/step - loss: 0.0461
Epoch 396/800
39/39 [==============================] - 0s 320us/step - loss: 0.0286
Epoch 397/800
39/39 [==============================] - 0s 274us/step - loss: 0.0287
Epoch 398/800
39/39 [==============================] - 0s 364us/step - loss: 0.0271
Epoch 399/800
39/39 [==============================] - 0s 458us/step - loss: 0.0404
Epoch 400/800
39/39 [==============================] - 0s 461us/step - loss: 0.0246
Epoch 401/800
39/39 [==============================] - 0s 503us/step - loss: 0.0341
Epoch 402/800
```

```
39/39 [==============================] - 0s 742us/step - loss: 0.0307
Epoch 403/800
39/39 [==============================] - 0s 608us/step - loss: 0.0418
Epoch 404/800
39/39 [==============================] - 0s 852us/step - loss: 0.0237
Epoch 405/800
39/39 [==============================] - 0s 507us/step - loss: 0.0457
Epoch 406/800
39/39 [==============================] - 0s 368us/step - loss: 0.0295
Epoch 407/800
39/39 [==============================] - 0s 449us/step - loss: 0.0256
Epoch 408/800
39/39 [==============================] - 0s 464us/step - loss: 0.0428
Epoch 409/800
39/39 [==============================] - 0s 339us/step - loss: 0.0247
Epoch 410/800
39/39 [==============================] - 0s 404us/step - loss: 0.0319
Epoch 411/800
39/39 [==============================] - 0s 673us/step - loss: 0.0351
Epoch 412/800
39/39 [==============================] - 0s 445us/step - loss: 0.0428
Epoch 413/800
39/39 [==============================] - 0s 381us/step - loss: 0.0389
Epoch 414/800
39/39 [==============================] - 0s 313us/step - loss: 0.0337
Epoch 415/800
39/39 [==============================] - 0s 347us/step - loss: 0.0359
Epoch 416/800
39/39 [==============================] - 0s 433us/step - loss: 0.0479
Epoch 417/800
39/39 [==============================] - 0s 408us/step - loss: 0.0421
Epoch 418/800
39/39 [==============================] - 0s 548us/step - loss: 0.0286
Epoch 419/800
39/39 [==============================] - 0s 581us/step - loss: 0.0379
Epoch 420/800
39/39 [==============================] - 0s 441us/step - loss: 0.0239
Epoch 421/800
39/39 [==============================] - 0s 316us/step - loss: 0.0237
Epoch 422/800
39/39 [==============================] - 0s 439us/step - loss: 0.0331
Epoch 423/800
39/39 [==============================] - 0s 396us/step - loss: 0.0311
Epoch 424/800
39/39 [==============================] - 0s 407us/step - loss: 0.0293
Epoch 425/800
39/39 [==============================] - 0s 719us/step - loss: 0.0434
Epoch 426/800
39/39 [==============================] - 0s 436us/step - loss: 0.0409
Epoch 427/800
39/39 [==============================] - 0s 375us/step - loss: 0.0333
Epoch 428/800
39/39 [==============================] - 0s 436us/step - loss: 0.0278
Epoch 429/800
39/39 [==============================] - 0s 466us/step - loss: 0.0237
Epoch 430/800
39/39 [==============================] - 0s 322us/step - loss: 0.0296
```

```
Epoch 431/800
39/39 [==============================] - 0s 326us/step - loss: 0.0342
Epoch 432/800
39/39 [==============================] - 0s 366us/step - loss: 0.0359
Epoch 433/800
39/39 [==============================] - 0s 385us/step - loss: 0.0320
Epoch 434/800
39/39 [==============================] - 0s 452us/step - loss: 0.0308
Epoch 435/800
39/39 [==============================] - 0s 881us/step - loss: 0.0354
Epoch 436/800
39/39 [==============================] - 0s 763us/step - loss: 0.0405
Epoch 437/800
39/39 [==============================] - 0s 837us/step - loss: 0.0247
Epoch 438/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0283
Epoch 439/800
39/39 [==============================] - 0s 594us/step - loss: 0.0397
Epoch 440/800
39/39 [==============================] - 0s 731us/step - loss: 0.0327
Epoch 441/800
39/39 [==============================] - 0s 617us/step - loss: 0.0261
Epoch 442/800
39/39 [==============================] - 0s 345us/step - loss: 0.0281
Epoch 443/800
39/39 [==============================] - 0s 345us/step - loss: 0.0440
Epoch 444/800
39/39 [==============================] - 0s 381us/step - loss: 0.0315
Epoch 445/800
39/39 [==============================] - 0s 434us/step - loss: 0.0223
Epoch 446/800
39/39 [==============================] - 0s 347us/step - loss: 0.0339
Epoch 447/800
39/39 [==============================] - 0s 408us/step - loss: 0.0343
Epoch 448/800
39/39 [==============================] - 0s 623us/step - loss: 0.0229
Epoch 449/800
39/39 [==============================] - 0s 529us/step - loss: 0.0244
Epoch 450/800
39/39 [==============================] - 0s 596us/step - loss: 0.0300
Epoch 451/800
39/39 [==============================] - 0s 410us/step - loss: 0.0268
Epoch 452/800
39/39 [==============================] - 0s 329us/step - loss: 0.0309
Epoch 453/800
39/39 [==============================] - 0s 376us/step - loss: 0.0357
Epoch 454/800
39/39 [==============================] - 0s 512us/step - loss: 0.0370
Epoch 455/800
39/39 [==============================] - 0s 886us/step - loss: 0.0408
Epoch 456/800
39/39 [==============================] - 0s 626us/step - loss: 0.0294
Epoch 457/800
39/39 [==============================] - 0s 687us/step - loss: 0.0361
Epoch 458/800
39/39 [==============================] - 0s 584us/step - loss: 0.0287
Epoch 459/800
```

```
39/39 [==============================] - 0s 566us/step - loss: 0.0224
Epoch 460/800
39/39 [==============================] - 0s 514us/step - loss: 0.0452
Epoch 461/800
39/39 [==============================] - 0s 389us/step - loss: 0.0250
Epoch 462/800
39/39 [==============================] - 0s 412us/step - loss: 0.0281
Epoch 463/800
39/39 [==============================] - 0s 732us/step - loss: 0.0275
Epoch 464/800
39/39 [==============================] - 0s 859us/step - loss: 0.0455
Epoch 465/800
39/39 [==============================] - 0s 431us/step - loss: 0.0387
Epoch 466/800
39/39 [==============================] - 0s 381us/step - loss: 0.0287
Epoch 467/800
39/39 [==============================] - 0s 411us/step - loss: 0.0438
Epoch 468/800
39/39 [==============================] - 0s 421us/step - loss: 0.0270
Epoch 469/800
39/39 [==============================] - 0s 332us/step - loss: 0.0361
Epoch 470/800
39/39 [==============================] - 0s 404us/step - loss: 0.0239
Epoch 471/800
39/39 [==============================] - 0s 383us/step - loss: 0.0462
Epoch 472/800
39/39 [==============================] - 0s 346us/step - loss: 0.0239
Epoch 473/800
39/39 [==============================] - 0s 397us/step - loss: 0.0233
Epoch 474/800
39/39 [==============================] - 0s 363us/step - loss: 0.0337
Epoch 475/800
39/39 [==============================] - 0s 431us/step - loss: 0.0388
Epoch 476/800
39/39 [==============================] - 0s 782us/step - loss: 0.0314
Epoch 477/800
39/39 [==============================] - 0s 762us/step - loss: 0.0431
Epoch 478/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0456
Epoch 479/800
39/39 [==============================] - 0s 502us/step - loss: 0.0267
Epoch 480/800
39/39 [==============================] - 0s 702us/step - loss: 0.0230
Epoch 481/800
39/39 [==============================] - 0s 425us/step - loss: 0.0278
Epoch 482/800
39/39 [==============================] - 0s 409us/step - loss: 0.0376
Epoch 483/800
39/39 [==============================] - 0s 350us/step - loss: 0.0302
Epoch 484/800
39/39 [==============================] - 0s 551us/step - loss: 0.0293
Epoch 485/800
39/39 [==============================] - 0s 701us/step - loss: 0.0250
Epoch 486/800
39/39 [==============================] - 0s 303us/step - loss: 0.0405
Epoch 487/800
39/39 [==============================] - 0s 304us/step - loss: 0.0256
```

```
Epoch 488/800
39/39 [==============================] - 0s 403us/step - loss: 0.0331
Epoch 489/800
39/39 [==============================] - 0s 489us/step - loss: 0.0408
Epoch 490/800
39/39 [==============================] - 0s 723us/step - loss: 0.0238
Epoch 491/800
39/39 [==============================] - 0s 846us/step - loss: 0.0224
Epoch 492/800
39/39 [==============================] - 0s 2ms/step - loss: 0.0266
Epoch 493/800
39/39 [==============================] - 0s 736us/step - loss: 0.0466
Epoch 494/800
39/39 [==============================] - 0s 972us/step - loss: 0.0239
Epoch 495/800
39/39 [==============================] - 0s 682us/step - loss: 0.0290
Epoch 496/800
39/39 [==============================] - 0s 506us/step - loss: 0.0516
Epoch 497/800
39/39 [==============================] - 0s 329us/step - loss: 0.0458
Epoch 498/800
39/39 [==============================] - 0s 382us/step - loss: 0.0400
Epoch 499/800
39/39 [==============================] - 0s 391us/step - loss: 0.0328
Epoch 500/800
39/39 [==============================] - 0s 297us/step - loss: 0.0346
Epoch 501/800
39/39 [==============================] - 0s 350us/step - loss: 0.0232
Epoch 502/800
39/39 [==============================] - 0s 320us/step - loss: 0.0293
Epoch 503/800
39/39 [==============================] - 0s 532us/step - loss: 0.0266
Epoch 504/800
39/39 [==============================] - 0s 466us/step - loss: 0.0233
Epoch 505/800
39/39 [==============================] - 0s 359us/step - loss: 0.0418
Epoch 506/800
39/39 [==============================] - 0s 408us/step - loss: 0.0228
Epoch 507/800
39/39 [==============================] - 0s 380us/step - loss: 0.0257
Epoch 508/800
39/39 [==============================] - 0s 324us/step - loss: 0.0302
Epoch 509/800
39/39 [==============================] - 0s 390us/step - loss: 0.0388
Epoch 510/800
39/39 [==============================] - 0s 483us/step - loss: 0.0226
Epoch 511/800
39/39 [==============================] - 0s 583us/step - loss: 0.0292
Epoch 512/800
39/39 [==============================] - 0s 305us/step - loss: 0.0458
Epoch 513/800
39/39 [==============================] - 0s 320us/step - loss: 0.0222
Epoch 514/800
39/39 [==============================] - 0s 286us/step - loss: 0.0465
Epoch 515/800
39/39 [==============================] - 0s 469us/step - loss: 0.0311
Epoch 516/800
```

```
39/39 [==============================] - 0s 405us/step - loss: 0.0280
Epoch 517/800
39/39 [==============================] - 0s 362us/step - loss: 0.0264
Epoch 518/800
39/39 [==============================] - 0s 723us/step - loss: 0.0228
Epoch 519/800
39/39 [==============================] - 0s 499us/step - loss: 0.0376
Epoch 520/800
39/39 [==============================] - 0s 733us/step - loss: 0.0278
Epoch 521/800
39/39 [==============================] - 0s 868us/step - loss: 0.0362
Epoch 522/800
39/39 [==============================] - 0s 794us/step - loss: 0.0255
Epoch 523/800
39/39 [==============================] - 0s 877us/step - loss: 0.0216
Epoch 524/800
39/39 [==============================] - 0s 445us/step - loss: 0.0233
Epoch 525/800
39/39 [==============================] - 0s 436us/step - loss: 0.0261
Epoch 526/800
39/39 [==============================] - 0s 401us/step - loss: 0.0358
Epoch 527/800
39/39 [==============================] - 0s 290us/step - loss: 0.0418
Epoch 528/800
39/39 [==============================] - 0s 568us/step - loss: 0.0223
Epoch 529/800
39/39 [==============================] - 0s 951us/step - loss: 0.0465
Epoch 530/800
39/39 [==============================] - 0s 767us/step - loss: 0.0237
Epoch 531/800
39/39 [==============================] - 0s 845us/step - loss: 0.0239
Epoch 532/800
39/39 [==============================] - 0s 688us/step - loss: 0.0315
Epoch 533/800
39/39 [==============================] - 0s 783us/step - loss: 0.0349
Epoch 534/800
39/39 [==============================] - 0s 985us/step - loss: 0.0263
Epoch 535/800
39/39 [==============================] - ETA: 0s - loss: 0.030 - 0s 655us/step
- loss: 0.0274
Epoch 536/800
39/39 [==============================] - 0s 781us/step - loss: 0.0351
Epoch 537/800
39/39 [==============================] - 0s 917us/step - loss: 0.0477
Epoch 538/800
39/39 [==============================] - 0s 548us/step - loss: 0.0290
Epoch 539/800
39/39 [==============================] - 0s 750us/step - loss: 0.0349
Epoch 540/800
39/39 [==============================] - 0s 411us/step - loss: 0.0270
Epoch 541/800
39/39 [==============================] - 0s 294us/step - loss: 0.0251
Epoch 542/800
39/39 [==============================] - 0s 326us/step - loss: 0.0433
Epoch 543/800
39/39 [==============================] - 0s 368us/step - loss: 0.0222
Epoch 544/800
```

```
39/39 [==============================] - 0s 467us/step - loss: 0.0340
Epoch 545/800
39/39 [==============================] - 0s 316us/step - loss: 0.0244
Epoch 546/800
39/39 [==============================] - 0s 317us/step - loss: 0.0212
Epoch 547/800
39/39 [==============================] - 0s 345us/step - loss: 0.0318
Epoch 548/800
39/39 [==============================] - 0s 374us/step - loss: 0.0333
Epoch 549/800
39/39 [==============================] - 0s 402us/step - loss: 0.0461
Epoch 550/800
39/39 [==============================] - 0s 311us/step - loss: 0.0247
Epoch 551/800
39/39 [==============================] - 0s 420us/step - loss: 0.0262
Epoch 552/800
39/39 [==============================] - 0s 539us/step - loss: 0.0253
Epoch 553/800
39/39 [==============================] - 0s 341us/step - loss: 0.0345
Epoch 554/800
39/39 [==============================] - 0s 513us/step - loss: 0.0552
Epoch 555/800
39/39 [==============================] - 0s 367us/step - loss: 0.0239
Epoch 556/800
39/39 [==============================] - 0s 288us/step - loss: 0.0456
Epoch 557/800
39/39 [==============================] - 0s 313us/step - loss: 0.0390
Epoch 558/800
39/39 [==============================] - 0s 639us/step - loss: 0.0401
Epoch 559/800
39/39 [==============================] - 0s 2ms/step - loss: 0.0262
Epoch 560/800
39/39 [==============================] - 0s 725us/step - loss: 0.0518
Epoch 561/800
39/39 [==============================] - 0s 391us/step - loss: 0.0258
Epoch 562/800
39/39 [==============================] - 0s 375us/step - loss: 0.0236
Epoch 563/800
39/39 [==============================] - 0s 532us/step - loss: 0.0210
Epoch 564/800
39/39 [==============================] - 0s 447us/step - loss: 0.0319
Epoch 565/800
39/39 [==============================] - 0s 401us/step - loss: 0.0225
Epoch 566/800
39/39 [==============================] - 0s 329us/step - loss: 0.0393
Epoch 567/800
39/39 [==============================] - 0s 339us/step - loss: 0.0352
Epoch 568/800
39/39 [==============================] - 0s 315us/step - loss: 0.0503
Epoch 569/800
39/39 [==============================] - 0s 372us/step - loss: 0.0319
Epoch 570/800
39/39 [==============================] - 0s 374us/step - loss: 0.0283
Epoch 571/800
39/39 [==============================] - 0s 361us/step - loss: 0.0315
Epoch 572/800
39/39 [==============================] - 0s 400us/step - loss: 0.0340
```

```
Epoch 573/800
39/39 [==============================] - 0s 414us/step - loss: 0.0258
Epoch 574/800
39/39 [==============================] - 0s 502us/step - loss: 0.0243
Epoch 575/800
39/39 [==============================] - 0s 460us/step - loss: 0.0224
Epoch 576/800
39/39 [==============================] - 0s 462us/step - loss: 0.0238
Epoch 577/800
39/39 [==============================] - 0s 410us/step - loss: 0.0282
Epoch 578/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0508
Epoch 579/800
39/39 [==============================] - 0s 371us/step - loss: 0.0214
Epoch 580/800
39/39 [==============================] - 0s 490us/step - loss: 0.0296
Epoch 581/800
39/39 [==============================] - 0s 456us/step - loss: 0.0420
Epoch 582/800
39/39 [==============================] - 0s 555us/step - loss: 0.0246
Epoch 583/800
39/39 [==============================] - 0s 568us/step - loss: 0.0310
Epoch 584/800
39/39 [==============================] - 0s 581us/step - loss: 0.0354
Epoch 585/800
39/39 [==============================] - 0s 377us/step - loss: 0.0295
Epoch 586/800
39/39 [==============================] - 0s 293us/step - loss: 0.0228
Epoch 587/800
39/39 [==============================] - 0s 333us/step - loss: 0.0374
Epoch 588/800
39/39 [==============================] - 0s 368us/step - loss: 0.0406
Epoch 589/800
39/39 [==============================] - 0s 262us/step - loss: 0.0231
Epoch 590/800
39/39 [==============================] - 0s 577us/step - loss: 0.0299
Epoch 591/800
39/39 [==============================] - 0s 337us/step - loss: 0.0478
Epoch 592/800
39/39 [==============================] - 0s 444us/step - loss: 0.0228
Epoch 593/800
39/39 [==============================] - 0s 347us/step - loss: 0.0309
Epoch 594/800
39/39 [==============================] - 0s 415us/step - loss: 0.0248
Epoch 595/800
39/39 [==============================] - 0s 597us/step - loss: 0.0473
Epoch 596/800
39/39 [==============================] - 0s 409us/step - loss: 0.0214
Epoch 597/800
39/39 [==============================] - 0s 397us/step - loss: 0.0349
Epoch 598/800
39/39 [==============================] - 0s 431us/step - loss: 0.0394
Epoch 599/800
39/39 [==============================] - 0s 366us/step - loss: 0.0248
Epoch 600/800
39/39 [==============================] - 0s 354us/step - loss: 0.0255
Epoch 601/800
```

```
39/39 [==============================] - 0s 358us/step - loss: 0.0369
Epoch 602/800
39/39 [==============================] - 0s 456us/step - loss: 0.0212
Epoch 603/800
39/39 [==============================] - 0s 891us/step - loss: 0.0290
Epoch 604/800
39/39 [==============================] - 0s 528us/step - loss: 0.0302
Epoch 605/800
39/39 [==============================] - 0s 345us/step - loss: 0.0262
Epoch 606/800
39/39 [==============================] - 0s 370us/step - loss: 0.0313
Epoch 607/800
39/39 [==============================] - 0s 429us/step - loss: 0.0343
Epoch 608/800
39/39 [==============================] - 0s 461us/step - loss: 0.0233
Epoch 609/800
39/39 [==============================] - 0s 413us/step - loss: 0.0224
Epoch 610/800
39/39 [==============================] - 0s 354us/step - loss: 0.0256
Epoch 611/800
39/39 [==============================] - 0s 430us/step - loss: 0.0549
Epoch 612/800
39/39 [==============================] - 0s 932us/step - loss: 0.0345
Epoch 613/800
39/39 [==============================] - 0s 582us/step - loss: 0.0339
Epoch 614/800
39/39 [==============================] - 0s 482us/step - loss: 0.0234
Epoch 615/800
39/39 [==============================] - 0s 518us/step - loss: 0.0294
Epoch 616/800
39/39 [==============================] - 0s 671us/step - loss: 0.0242
Epoch 617/800
39/39 [==============================] - 0s 782us/step - loss: 0.0434
Epoch 618/800
39/39 [==============================] - 0s 381us/step - loss: 0.0250
Epoch 619/800
39/39 [==============================] - 0s 317us/step - loss: 0.0321
Epoch 620/800
39/39 [==============================] - 0s 510us/step - loss: 0.0401
Epoch 621/800
39/39 [==============================] - 0s 824us/step - loss: 0.0429
Epoch 622/800
39/39 [==============================] - 0s 983us/step - loss: 0.0223
Epoch 623/800
39/39 [==============================] - 0s 633us/step - loss: 0.0244
Epoch 624/800
39/39 [==============================] - 0s 750us/step - loss: 0.0208
Epoch 625/800
39/39 [==============================] - 0s 465us/step - loss: 0.0405
Epoch 626/800
39/39 [==============================] - 0s 397us/step - loss: 0.0332
Epoch 627/800
39/39 [==============================] - 0s 515us/step - loss: 0.0289
Epoch 628/800
39/39 [==============================] - 0s 409us/step - loss: 0.0305
Epoch 629/800
39/39 [==============================] - 0s 405us/step - loss: 0.0360
```

```
Epoch 630/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0405
Epoch 631/800
39/39 [==============================] - 0s 886us/step - loss: 0.0323
Epoch 632/800
39/39 [==============================] - 0s 485us/step - loss: 0.0241
Epoch 633/800
39/39 [==============================] - 0s 314us/step - loss: 0.0229
Epoch 634/800
39/39 [==============================] - 0s 378us/step - loss: 0.0319
Epoch 635/800
39/39 [==============================] - 0s 433us/step - loss: 0.0261
Epoch 636/800
39/39 [==============================] - 0s 331us/step - loss: 0.0400
Epoch 637/800
39/39 [==============================] - 0s 496us/step - loss: 0.0298
Epoch 638/800
39/39 [==============================] - 0s 503us/step - loss: 0.0335
Epoch 639/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0244
Epoch 640/800
39/39 [==============================] - 0s 435us/step - loss: 0.0338
Epoch 641/800
39/39 [==============================] - 0s 338us/step - loss: 0.0283
Epoch 642/800
39/39 [==============================] - 0s 383us/step - loss: 0.0394
Epoch 643/800
39/39 [==============================] - 0s 476us/step - loss: 0.0214
Epoch 644/800
39/39 [==============================] - 0s 663us/step - loss: 0.0244
Epoch 645/800
39/39 [==============================] - 0s 473us/step - loss: 0.0388
Epoch 646/800
39/39 [==============================] - 0s 366us/step - loss: 0.0247
Epoch 647/800
39/39 [==============================] - 0s 389us/step - loss: 0.0213
Epoch 648/800
39/39 [==============================] - 0s 350us/step - loss: 0.0241
Epoch 649/800
39/39 [==============================] - 0s 354us/step - loss: 0.0293
Epoch 650/800
39/39 [==============================] - 0s 880us/step - loss: 0.0242
Epoch 651/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0460
Epoch 652/800
39/39 [==============================] - 0s 550us/step - loss: 0.0206
Epoch 653/800
39/39 [==============================] - 0s 431us/step - loss: 0.0212
Epoch 654/800
39/39 [==============================] - 0s 483us/step - loss: 0.0448
Epoch 655/800
39/39 [==============================] - 0s 383us/step - loss: 0.0498
Epoch 656/800
39/39 [==============================] - 0s 459us/step - loss: 0.0421
Epoch 657/800
39/39 [==============================] - 0s 402us/step - loss: 0.0339
Epoch 658/800
```

```
39/39 [==============================] - 0s 800us/step - loss: 0.0368
Epoch 659/800
39/39 [==============================] - 0s 820us/step - loss: 0.0258
Epoch 660/800
39/39 [==============================] - 0s 368us/step - loss: 0.0322
Epoch 661/800
39/39 [==============================] - 0s 406us/step - loss: 0.0229
Epoch 662/800
39/39 [==============================] - 0s 346us/step - loss: 0.0223
Epoch 663/800
39/39 [==============================] - 0s 381us/step - loss: 0.0352
Epoch 664/800
39/39 [==============================] - 0s 636us/step - loss: 0.0431
Epoch 665/800
39/39 [==============================] - 0s 401us/step - loss: 0.0243
Epoch 666/800
39/39 [==============================] - 0s 326us/step - loss: 0.0209
Epoch 667/800
39/39 [==============================] - 0s 347us/step - loss: 0.0376
Epoch 668/800
39/39 [==============================] - 0s 306us/step - loss: 0.0418
Epoch 669/800
39/39 [==============================] - 0s 300us/step - loss: 0.0270
Epoch 670/800
39/39 [==============================] - 0s 378us/step - loss: 0.0232
Epoch 671/800
39/39 [==============================] - 0s 662us/step - loss: 0.0309
Epoch 672/800
39/39 [==============================] - 0s 441us/step - loss: 0.0275
Epoch 673/800
39/39 [==============================] - 0s 382us/step - loss: 0.0282
Epoch 674/800
39/39 [==============================] - 0s 415us/step - loss: 0.0421
Epoch 675/800
39/39 [==============================] - 0s 372us/step - loss: 0.0272
Epoch 676/800
39/39 [==============================] - 0s 339us/step - loss: 0.0321
Epoch 677/800
39/39 [==============================] - 0s 309us/step - loss: 0.0286
Epoch 678/800
39/39 [==============================] - 0s 270us/step - loss: 0.0276
Epoch 679/800
39/39 [==============================] - 0s 310us/step - loss: 0.0324
Epoch 680/800
39/39 [==============================] - 0s 347us/step - loss: 0.0314
Epoch 681/800
39/39 [==============================] - 0s 306us/step - loss: 0.0241
Epoch 682/800
39/39 [==============================] - 0s 251us/step - loss: 0.0241
Epoch 683/800
39/39 [==============================] - 0s 298us/step - loss: 0.0277
Epoch 684/800
39/39 [==============================] - 0s 282us/step - loss: 0.0364
Epoch 685/800
39/39 [==============================] - 0s 340us/step - loss: 0.0379
Epoch 686/800
39/39 [==============================] - 0s 356us/step - loss: 0.0408
```

```
Epoch 687/800
39/39 [==============================] - 0s 318us/step - loss: 0.0263
Epoch 688/800
39/39 [==============================] - 0s 392us/step - loss: 0.0314
Epoch 689/800
39/39 [==============================] - 0s 318us/step - loss: 0.0227
Epoch 690/800
39/39 [==============================] - 0s 329us/step - loss: 0.0311
Epoch 691/800
39/39 [==============================] - 0s 409us/step - loss: 0.0403
Epoch 692/800
39/39 [==============================] - 0s 319us/step - loss: 0.0229
Epoch 693/800
39/39 [==============================] - 0s 433us/step - loss: 0.0296
Epoch 694/800
39/39 [==============================] - 0s 803us/step - loss: 0.0245
Epoch 695/800
39/39 [==============================] - 0s 414us/step - loss: 0.0385
Epoch 696/800
39/39 [==============================] - 0s 542us/step - loss: 0.0338
Epoch 697/800
39/39 [==============================] - 0s 377us/step - loss: 0.0269
Epoch 698/800
39/39 [==============================] - 0s 458us/step - loss: 0.0372
Epoch 699/800
39/39 [==============================] - 0s 397us/step - loss: 0.0283
Epoch 700/800
39/39 [==============================] - 0s 395us/step - loss: 0.0215
Epoch 701/800
39/39 [==============================] - 0s 370us/step - loss: 0.0404
Epoch 702/800
39/39 [==============================] - 0s 474us/step - loss: 0.0316
Epoch 703/800
39/39 [==============================] - 0s 473us/step - loss: 0.0316
Epoch 704/800
39/39 [==============================] - 0s 430us/step - loss: 0.0444
Epoch 705/800
39/39 [==============================] - 0s 561us/step - loss: 0.0278
Epoch 706/800
39/39 [==============================] - 0s 631us/step - loss: 0.0322
Epoch 707/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0312
Epoch 708/800
39/39 [==============================] - 0s 780us/step - loss: 0.0209
Epoch 709/800
39/39 [==============================] - 0s 411us/step - loss: 0.0459
Epoch 710/800
39/39 [==============================] - 0s 396us/step - loss: 0.0236
Epoch 711/800
39/39 [==============================] - 0s 459us/step - loss: 0.0327
Epoch 712/800
39/39 [==============================] - 0s 389us/step - loss: 0.0234
Epoch 713/800
39/39 [==============================] - 0s 376us/step - loss: 0.0209
Epoch 714/800
39/39 [==============================] - 0s 737us/step - loss: 0.0247
Epoch 715/800
```

```
39/39 [==============================] - 0s 502us/step - loss: 0.0397
Epoch 716/800
39/39 [==============================] - 0s 378us/step - loss: 0.0407
Epoch 717/800
39/39 [==============================] - 0s 364us/step - loss: 0.0292
Epoch 718/800
39/39 [==============================] - 0s 349us/step - loss: 0.0253
Epoch 719/800
39/39 [==============================] - 0s 306us/step - loss: 0.0387
Epoch 720/800
39/39 [==============================] - 0s 443us/step - loss: 0.0225
Epoch 721/800
39/39 [==============================] - 0s 782us/step - loss: 0.0205
Epoch 722/800
39/39 [==============================] - 0s 520us/step - loss: 0.0284
Epoch 723/800
39/39 [==============================] - 0s 369us/step - loss: 0.0371
Epoch 724/800
39/39 [==============================] - 0s 455us/step - loss: 0.0299
Epoch 725/800
39/39 [==============================] - 0s 403us/step - loss: 0.0342
Epoch 726/800
39/39 [==============================] - 0s 716us/step - loss: 0.0197
Epoch 727/800
39/39 [==============================] - 0s 442us/step - loss: 0.0327
Epoch 728/800
39/39 [==============================] - 0s 497us/step - loss: 0.0283
Epoch 729/800
39/39 [==============================] - 0s 449us/step - loss: 0.0215
Epoch 730/800
39/39 [==============================] - 0s 734us/step - loss: 0.0264
Epoch 731/800
39/39 [==============================] - 0s 407us/step - loss: 0.0424
Epoch 732/800
39/39 [==============================] - 0s 371us/step - loss: 0.0253
Epoch 733/800
39/39 [==============================] - 0s 369us/step - loss: 0.0203
Epoch 734/800
39/39 [==============================] - 0s 371us/step - loss: 0.0257
Epoch 735/800
39/39 [==============================] - 0s 405us/step - loss: 0.0285
Epoch 736/800
39/39 [==============================] - 0s 494us/step - loss: 0.0295
Epoch 737/800
39/39 [==============================] - 0s 821us/step - loss: 0.0370
Epoch 738/800
39/39 [==============================] - 0s 333us/step - loss: 0.0360
Epoch 739/800
39/39 [==============================] - 0s 407us/step - loss: 0.0313
Epoch 740/800
39/39 [==============================] - 0s 333us/step - loss: 0.0319
Epoch 741/800
39/39 [==============================] - 0s 306us/step - loss: 0.0335
Epoch 742/800
39/39 [==============================] - 0s 377us/step - loss: 0.0226
Epoch 743/800
39/39 [==============================] - 0s 298us/step - loss: 0.0348
```

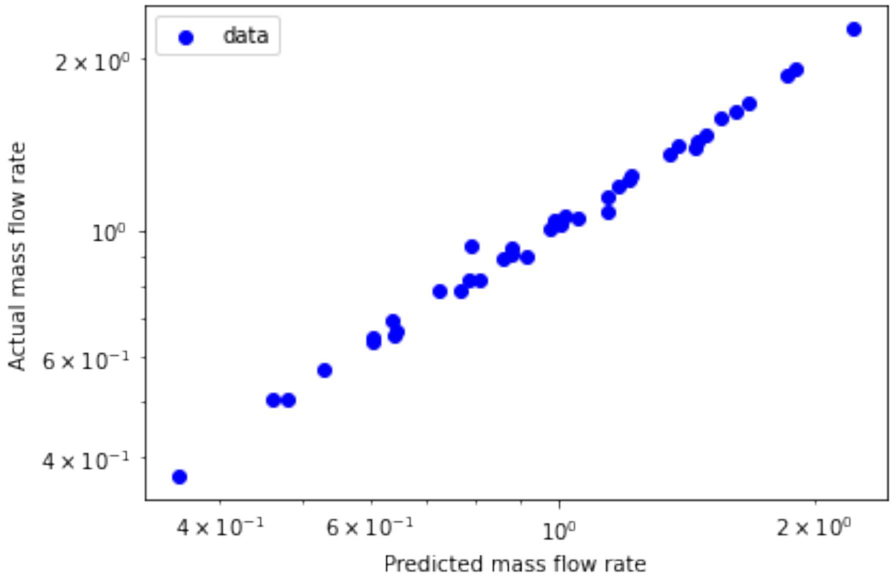
```
Epoch 744/800
39/39 [==============================] - 0s 326us/step - loss: 0.0213
Epoch 745/800
39/39 [==============================] - 0s 336us/step - loss: 0.0224
Epoch 746/800
39/39 [==============================] - 0s 279us/step - loss: 0.0403
Epoch 747/800
39/39 [==============================] - 0s 311us/step - loss: 0.0340
Epoch 748/800
39/39 [==============================] - 0s 499us/step - loss: 0.0391
Epoch 749/800
39/39 [==============================] - 0s 661us/step - loss: 0.0386
Epoch 750/800
39/39 [==============================] - 0s 376us/step - loss: 0.0313
Epoch 751/800
39/39 [==============================] - 0s 409us/step - loss: 0.0277
Epoch 752/800
39/39 [==============================] - 0s 302us/step - loss: 0.0391
Epoch 753/800
39/39 [==============================] - 0s 398us/step - loss: 0.0218
Epoch 754/800
39/39 [==============================] - 0s 393us/step - loss: 0.0386
Epoch 755/800
39/39 [==============================] - 0s 345us/step - loss: 0.0336
Epoch 756/800
39/39 [==============================] - 0s 418us/step - loss: 0.0240
Epoch 757/800
39/39 [==============================] - 0s 530us/step - loss: 0.0203
Epoch 758/800
39/39 [==============================] - 0s 445us/step - loss: 0.0257
Epoch 759/800
39/39 [==============================] - 0s 425us/step - loss: 0.0281
Epoch 760/800
39/39 [==============================] - 0s 309us/step - loss: 0.0210
Epoch 761/800
39/39 [==============================] - 0s 368us/step - loss: 0.0405
Epoch 762/800
39/39 [==============================] - 0s 381us/step - loss: 0.0470
Epoch 763/800
39/39 [==============================] - 0s 379us/step - loss: 0.0257
Epoch 764/800
39/39 [==============================] - 0s 323us/step - loss: 0.0212
Epoch 765/800
39/39 [==============================] - 0s 356us/step - loss: 0.0200
Epoch 766/800
39/39 [==============================] - 0s 446us/step - loss: 0.0263
Epoch 767/800
39/39 [==============================] - 0s 494us/step - loss: 0.0312
Epoch 768/800
39/39 [==============================] - 0s 2ms/step - loss: 0.0204
Epoch 769/800
39/39 [==============================] - 0s 580us/step - loss: 0.0219
Epoch 770/800
39/39 [==============================] - 0s 808us/step - loss: 0.0484
Epoch 771/800
39/39 [==============================] - 0s 507us/step - loss: 0.0404
Epoch 772/800
```

```
39/39 [==============================] - ETA: 0s - loss: 0.025 - 0s 626us/step
- loss: 0.0252
Epoch 773/800
39/39 [==============================] - 0s 481us/step - loss: 0.0255
Epoch 774/800
39/39 [==============================] - 0s 452us/step - loss: 0.0340
Epoch 775/800
39/39 [==============================] - 0s 489us/step - loss: 0.0306
Epoch 776/800
39/39 [==============================] - 0s 1ms/step - loss: 0.0261
Epoch 777/800
39/39 [==============================] - 0s 497us/step - loss: 0.0246
Epoch 778/800
39/39 [==============================] - 0s 487us/step - loss: 0.0197
Epoch 779/800
39/39 [==============================] - 0s 381us/step - loss: 0.0269
Epoch 780/800
39/39 [==============================] - 0s 458us/step - loss: 0.0374
Epoch 781/800
39/39 [==============================] - 0s 368us/step - loss: 0.0361
Epoch 782/800
39/39 [==============================] - ETA: 0s - loss: 0.037 - 0s 505us/step
- loss: 0.0340
Epoch 783/800
39/39 [==============================] - 0s 340us/step - loss: 0.0291
Epoch 784/800
39/39 [==============================] - 0s 398us/step - loss: 0.0214
Epoch 785/800
39/39 [==============================] - 0s 386us/step - loss: 0.0323
Epoch 786/800
39/39 [==============================] - 0s 337us/step - loss: 0.0472
Epoch 787/800
39/39 [==============================] - 0s 783us/step - loss: 0.0375
Epoch 788/800
39/39 [==============================] - 0s 419us/step - loss: 0.0293
Epoch 789/800
39/39 [==============================] - 0s 332us/step - loss: 0.0333
Epoch 790/800
39/39 [==============================] - 0s 893us/step - loss: 0.0428
Epoch 791/800
39/39 [==============================] - 0s 519us/step - loss: 0.0206
Epoch 792/800
39/39 [==============================] - 0s 392us/step - loss: 0.0409
Epoch 793/800
39/39 [==============================] - 0s 428us/step - loss: 0.0215
Epoch 794/800
39/39 [==============================] - 0s 520us/step - loss: 0.0468
Epoch 795/800
39/39 [==============================] - 0s 323us/step - loss: 0.0335
Epoch 796/800
39/39 [==============================] - 0s 339us/step - loss: 0.0307
Epoch 797/800
39/39 [==============================] - 0s 685us/step - loss: 0.0262
Epoch 798/800
39/39 [==============================] - 0s 949us/step - loss: 0.0216
Epoch 799/800
39/39 [==============================] - 0s 433us/step - loss: 0.0295
```

```
Epoch 800/800
39/39 [==============================] - 0s 495us/step - loss: 0.0224
best epoch =  778
smallest loss = 0.019650723594121445
```

In [49]:

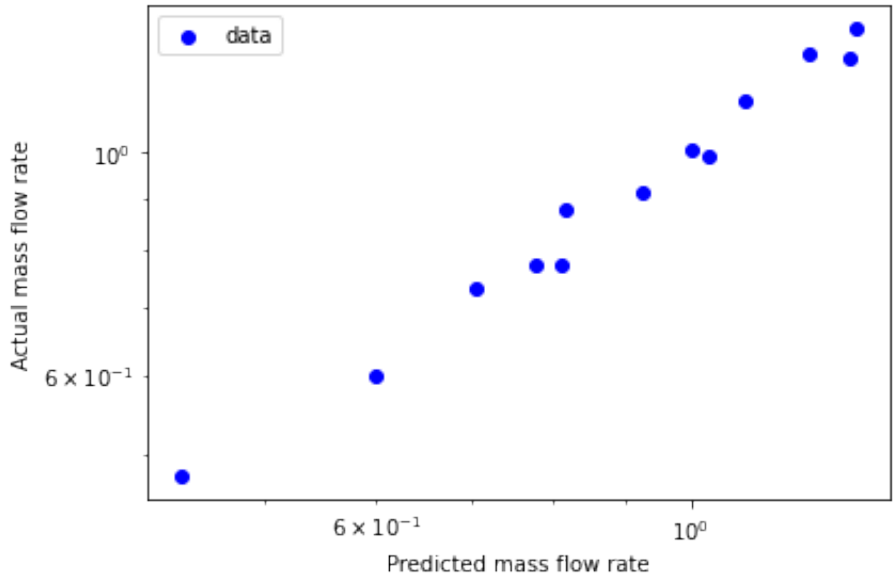
```
# Task 1.3e
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model3 = keras.models.load_model("best_modelv3")

import matplotlib.pyplot as plt

mdotpred = []

for i in range(len(X_train3)):
    test3 = [[X_train3[i][0], X_train3[i][1], X_train3[i][2], X_train3[i][3]]
    testarray3 = np.array(test3)
    a3 = recon_model3.predict(testarray3)
    mdotpred.append([a3[0][0]])

mdotorig = y_train3

plt.figure()
ax = plt.gca()
ax.scatter(mdotpred ,mdotorig , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.xlabel("Predicted mass flow rate")
plt.ylabel("Actual mass flow rate")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_mdot = metrics.mean_absolute_error(mdotpred,mdotorig)
print('mean absolute error between predictions and the collection of test dat
```




```
mean absolute error between predictions and the collection of test data: Mdot
= 0.030806486495235645
```

In [51]:

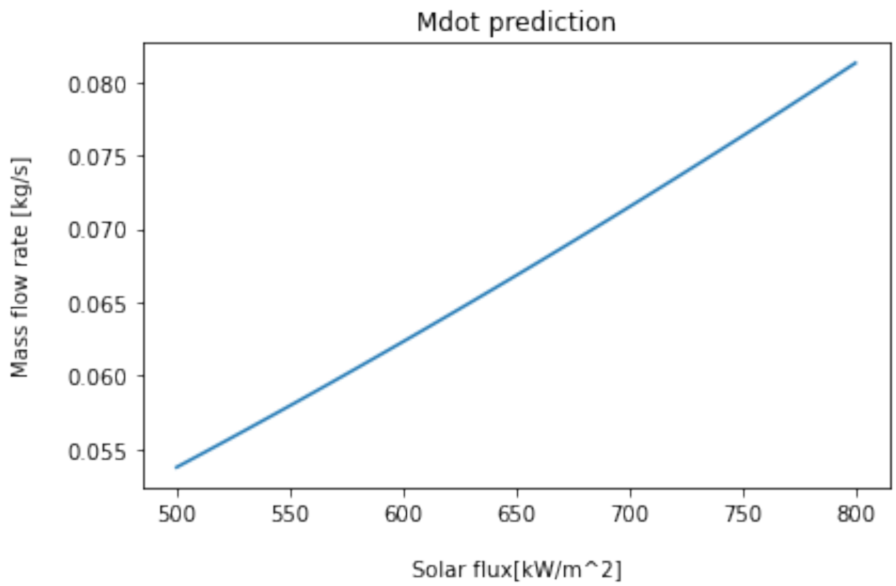
```
# Task 1.3f
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model3 = keras.models.load_model("best_modelv3")

import matplotlib.pyplot as plt

mdotpred2 = []

for i in range(len(X_test3)):
    testv3 = [[X_test3[i][0], X_test3[i][1], X_test3[i][2], X_test3[i][3]]]
    testarrayv3 = np.array(testv3)
    at3 = recon_model3.predict(testarrayv3)
    mdotpred2.append([at3[0][0]])

mdotorig2 = y_test3

plt.figure()
ax = plt.gca()
ax.scatter(mdotpred2 ,mdotorig2 , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.xlabel("Predicted mass flow rate")
plt.ylabel("Actual mass flow rate")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_mdot2 = metrics.mean_absolute_error(mdotpred2,mdotorig2)
print('mean absolute error between predictions and the collection of test dat
```



mean absolute error between predictions and the collection of test data: Mdot = 0.02914950802617285

In [30]:

```
#Task1.3g
Di = 0.010
X = np.linspace(500, 800) #qo
xe = 0.70
Tw = 300

recon_model3 = keras.models.load_model("best_modelv3")
testdatap = []
predmdot = [] #output

Din = Di/medDi3
Xn = X/medq03
xen = xe/medxe3
Twn = Tw/medTw3

for x in range(len(Xn)):
    testp = [[Din, Xn[x], xen, Twn]]
    testarrayp = np.array(testp)
    outptp = recon_model3.predict(testarrayp)
    predmdot.append(outptp[0][0]*medmdot3)

fig = plt.figure()
ax = plt.axes()
ax.plot(X, predmdot)
ax.set_ylabel('Mass flow rate [kg/s]')
ax.set_xlabel('Solar flux[kW/m^2]',)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.title.set_text('Mdot prediction');
plt.tight_layout()
plt.show()
```



In [1]:

```
#Task 2

import numpy as np

xdata = []
ydata = []

#xdata.append([qflux1 (W/m^2), qflux2 (W/m^2), separation distance (m)])
xdata.append([200.0,  100.0, 0.000])
xdata.append([200.0,  400.0, 0.000])
xdata.append([200.0,  200.0, 0.000])
xdata.append([500.0,  400.0, 0.000])
xdata.append([100.0,  300.0, 0.000])
xdata.append([600.0,  300.0, 0.002])
xdata.append([500.0,  400.0, 0.002])
xdata.append([200.,  400.0, 0.002])
xdata.append([100.0,  300.0, 0.002])
xdata.append([200.0,  200.0, 0.002])
xdata.append([200.0,  100.0, 0.002])
xdata.append([100.0,  200.0, 0.002])
xdata.append([500.0,  400.0, 0.004])
xdata.append([300.0,  400.0, 0.004])
xdata.append([200.0,  400.0, 0.004])
xdata.append([100.0,  400.0, 0.004])
xdata.append([100.0,  300.0, 0.004])
xdata.append([200.0,  300.0, 0.004])
xdata.append([500.0,  300.0, 0.004])
xdata.append([200.0,  100.0, 0.004])
xdata.append([100.0,  200.0, 0.004])
xdata.append([200.0,  200.0, 0.004])
xdata.append([300.0,  200.0, 0.004])
xdata.append([100.0,  300.0, 0.006])
xdata.append([200.0,  400.0, 0.006])
xdata.append([400.0,  200.0, 0.006])
```

```
xdata.append([600.0,  300.0, 0.006])
xdata.append([300.0,  600.0, 0.006])
xdata.append([200.0,  100.0, 0.006])
xdata.append([100.0,  200.0, 0.006])
xdata.append([50.0,  200.0, 0.006])
xdata.append([350.0,  150.0, 0.004])
xdata.append([350.0,  150.0, 0.008])
xdata.append([300.0,  200.0, 0.008])
xdata.append([200.0,  100.0, 0.008])
xdata.append([250.0,  50.0, 0.008])
xdata.append([50.0,  250.0, 0.008])
xdata.append([400.0,  300.0, 0.008])
xdata.append([500.0,  400.0, 0.008])
xdata.append([50.0,  200.0, 0.010])
xdata.append([100.0,  200.0, 0.010])
xdata.append([200.0,  200.0, 0.010])
xdata.append([300.0,  200.0, 0.010])
xdata.append([500.0,  400.0, 0.010])
xdata.append([400.0,  300.0, 0.010])
xdata.append([100.0,  100.0, 0.010])
xdata.append([200.0,  100.0, 0.010])

#xdata.append([maximum surface temperature (deg C)])
ydata.append([52.7])
ydata.append([72.2])
ydata.append([56.0])
ydata.append([77.2])
ydata.append([62.8])
ydata.append([84.6])
ydata.append([77.2])
ydata.append([71.6])
ydata.append([62.4])
ydata.append([55.3])
ydata.append([52.7])
ydata.append([53.9])
ydata.append([77.2])
ydata.append([72.2])
ydata.append([71.1])
ydata.append([70.2])
ydata.append([62.2])
ydata.append([63.2])
ydata.append([77.2])
ydata.append([52.7])
ydata.append([53.6])
ydata.append([54.8])
ydata.append([61.4])
ydata.append([62.0])
ydata.append([70.8])
ydata.append([69.5])
ydata.append([84.6])
ydata.append([86.4])
ydata.append([52.7])
ydata.append([53.4])
```

```
ydata.append([53.0])
ydata.append([65.5])
ydata.append([65.5])
ydata.append([61.4])
ydata.append([52.7])
ydata.append([57.1])
ydata.append([57.4])
ydata.append([69.5])
ydata.append([77.2])
ydata.append([52.9])
ydata.append([53.2])
ydata.append([53.9])
ydata.append([61.4])
ydata.append([77.2])
ydata.append([69.5])
ydata.append([43.6])
ydata.append([52.7])

xarray4= np.array(xdata)
yarray4= np.array(ydata)
```

In [4]:

```
#Task 2.1a
import keras
import pandas as pd
from keras.models import Sequential
import numpy as np
import keras.backend as kb
import tensorflow as tf
import statistics as s
#the follwoing 2 lines are only needed for Mac OS machines
import os
os.environ['KMP_DUPLICATE_LIB_OK']='True'


q1 =[] #inputs
q2 =[]
dx = []
Ts =[] #output

xarrayn4 = []
yarrayn4 = []

for x in range(len(xarray4)):
    q1.append(xarray4[x][0])
    q2.append(xarray4[x][1])
    dx.append(xarray4[x][2])

for y in range(len(yarray4)):
    Ts.append(yarray4[y][0])

medq1 = np.median(q1)
medq2 = np.median(q2)
meddx = np.median(dx)
medTs = np.median(Ts)

q1n = q1/medq1
q2n = q2/medq2
dxn = dx/meddx
Tsn = Ts/medTs
xarrayn4 = np.column_stack((q1n, q2n, dxn))
yarrayn4 = Tsn

print(xarrayn4)
print(yarrayn4)
```

```
Using TensorFlow backend.
[[1.   0.5  0.  ]
 [1.   2.   0.  ]
 [1.   1.   0.  ]
 [2.5  2.   0.  ]
 [0.5  1.5  0.  ]
 [3.   1.5  0.5 ]
 [2.5  2.   0.5 ]
 [1.   2.   0.5 ]
 [0.5  1.5  0.5 ]
 [1.   1.   0.5 ]
 [1.   0.5  0.5 ]
 [0.5  1.   0.5 ]
 [2.5  2.   1.  ]
 [1.5  2.   1.  ]
 [1.   2.   1.  ]
 [0.5  2.   1.  ]
 [0.5  1.5  1.  ]
 [1.   1.5  1.  ]
 [2.5  1.5  1.  ]
 [1.   0.5  1.  ]
 [0.5  1.   1.  ]
 [1.   1.   1.  ]
 [1.5  1.   1.  ]
 [0.5  1.5  1.5 ]
 [1.   2.   1.5 ]
 [2.   1.   1.5 ]
 [3.   1.5  1.5 ]
 [1.5  3.   1.5 ]
 [1.   0.5  1.5 ]
 [0.5  1.   1.5 ]
 [0.25 1.   1.5 ]
 [1.75 0.75 1.  ]
 [1.75 0.75 2.  ]
 [1.5  1.   2.  ]
 [1.   0.5  2.  ]
 [1.25 0.25 2.  ]
 [0.25 1.25 2.  ]
 [2.   1.5  2.  ]
 [2.5  2.   2.  ]
 [0.25 1.   2.5 ]
 [0.5  1.   2.5 ]
 [1.   1.   2.5 ]
 [1.5  1.   2.5 ]
 [2.5  2.   2.5 ]
 [2.   1.5  2.5 ]
 [0.5  0.5  2.5 ]
 [1.   0.5  2.5 ]]
[0.84726688 1.1607717  0.90032154 1.24115756 1.0096463  1.36012862
 1.24115756 1.1511254  1.00321543 0.88906752 0.84726688 0.86655949
 1.24115756 1.1607717  1.14308682 1.12861736 1.         1.01607717
 1.24115756 0.84726688 0.86173633 0.88102894 0.98713826 0.99678457
 1.13826367 1.11736334 1.36012862 1.38906752 0.84726688 0.8585209
 0.85209003 1.05305466 1.05305466 0.98713826 0.84726688 0.91800643
 0.92282958 1.11736334 1.24115756 0.85048232 0.85530547 0.86655949
 0.98713826 1.24115756 1.11736334 0.70096463 0.84726688]
```

In [5]:

```
#Task 2.1b
from sklearn.model_selection import train_test_split

X_train4, X_test4, y_train4, y_test4 = train_test_split(xarrayn4, yarrayn4, t

print(X_train4)
print(y_train4)
print(X_test4)
print(y_test4)
```

```
[[2.5  2.   0.5 ]
 [0.5  1.   2.5 ]
 [1.5  1.   2.  ]
 [1.5  2.   1.  ]
 [1.   1.5  1.  ]
 [2.   1.5  2.5 ]
 [0.5  2.   1.  ]
 [1.   1.   0.5 ]
 [0.5  1.5  1.  ]
 [0.5  1.   1.5 ]
 [1.75 0.75 2.  ]
 [0.5  0.5  2.5 ]
 [1.   0.5  0.  ]
 [1.75 0.75 1.  ]
 [0.25 1.   1.5 ]
 [3.   1.5  0.5 ]
 [0.5  1.   0.5 ]
 [1.   0.5  2.  ]
 [1.   2.   0.  ]
 [1.   1.   2.5 ]
 [1.   1.   1.  ]
 [1.   1.   0.  ]
 [1.25 0.25 2.  ]
 [0.5  1.5  1.5 ]
 [2.   1.5  2.  ]
 [1.   0.5  0.5 ]
 [1.5  1.   1.  ]
 [2.5  1.5  1.  ]
 [1.   0.5  2.5 ]
 [0.5  1.   1.  ]
 [1.   2.   0.5 ]
 [1.5  1.   2.5 ]
 [1.   2.   1.  ]
 [1.   0.5  1.5 ]
 [2.5  2.   2.  ]]
[1.24115756 0.85530547 0.98713826 1.1607717  1.01607717 1.11736334
 1.12861736 0.88906752 1.         0.8585209  1.05305466 0.70096463
 0.84726688 1.05305466 0.85209003 1.36012862 0.86655949 0.84726688
 1.1607717  0.86655949 0.88102894 0.90032154 0.91800643 0.99678457
 1.11736334 0.84726688 0.98713826 1.24115756 0.84726688 0.86173633
 1.1511254  0.98713826 1.14308682 0.84726688 1.24115756]
[[1.5  3.   1.5 ]
 [0.25 1.   2.5 ]
 [3.   1.5  1.5 ]
 [2.5  2.   2.5 ]
 [1.   2.   1.5 ]
 [0.25 1.25 2.  ]
 [2.5  2.   1.  ]
 [1.   0.5  1.  ]
 [0.5  1.5  0.  ]
 [2.   1.   1.5 ]
 [0.5  1.5  0.5 ]
 [2.5  2.   0.  ]]
[1.38906752 0.85048232 1.36012862 1.24115756 1.13826367 0.92282958
 1.24115756 0.84726688 1.0096463  1.11736334 1.00321543 1.24115756]
```

In [6]:

```
# define neural network model

from keras import backend as K
#initialize weights
initializer = keras.initializers.RandomUniform(minval= -0.2, maxval=0.5)

modelv4 = keras.Sequential([
    keras.layers.Dense(8, activation=K.elu, input_shape=[3],  kernel_initiali
    keras.layers.Dense(16, activation=K.elu,  kernel_initializer=initializer)
    keras.layers.Dense(16, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(16, activation=K.elu, kernel_initializer=initializer),
    keras.layers.Dense(1,  kernel_initializer=initializer)
  ])
```

In [7]:

```
#from tf.keras import optimizers
rms = keras.optimizers.RMSprop(0.001)
modelv4.compile(loss='mean_absolute_error',optimizer=rms)
```

In [8]:

```
# Add an early stopping callback
es = keras.callbacks.EarlyStopping(
    monitor='loss',
    mode='min',
    patience = 80,
    restore_best_weights = True,
    verbose=1)
# Add a checkpoint where loss is minimum, and save that model
mc = keras.callbacks.ModelCheckpoint('best_modelv4.SB', monitor='loss',
                         mode='min',  verbose=1, save_best_only=True)

historyData4 = modelv4.fit(X_train4,y_train4,epochs=800,callbacks=[es])

loss_hist4 = historyData4.history['loss']
#The above line will return a dictionary, access it's info like this:
best_epoch4 = np.argmin(historyData4.history['loss']) + 1
print ('best epoch = ', best_epoch4)
print('smallest loss =', np.min(loss_hist4))

modelv4.save('./best_modelv4')
```

```
Epoch 1/800
35/35 [==============================] - 2s 60ms/step - loss: 4.8200
Epoch 2/800
35/35 [==============================] - 0s 439us/step - loss: 3.7159
Epoch 3/800
35/35 [==============================] - 0s 416us/step - loss: 3.0676
Epoch 4/800
35/35 [==============================] - 0s 2ms/step - loss: 2.4587
Epoch 5/800
35/35 [==============================] - 0s 973us/step - loss: 2.0797
Epoch 6/800
```

```
35/35 [==============================] - 0s 349us/step - loss: 1.7719
Epoch 7/800
35/35 [==============================] - 0s 396us/step - loss: 1.4710
Epoch 8/800
35/35 [==============================] - 0s 315us/step - loss: 1.2587
Epoch 9/800
35/35 [==============================] - 0s 344us/step - loss: 1.1062
Epoch 10/800
35/35 [==============================] - 0s 431us/step - loss: 1.0396
Epoch 11/800
35/35 [==============================] - 0s 242us/step - loss: 0.9621
Epoch 12/800
35/35 [==============================] - 0s 446us/step - loss: 0.9324
Epoch 13/800
35/35 [==============================] - 0s 358us/step - loss: 0.8834
Epoch 14/800
35/35 [==============================] - 0s 443us/step - loss: 0.8536
Epoch 15/800
35/35 [==============================] - 0s 297us/step - loss: 0.8241
Epoch 16/800
35/35 [==============================] - 0s 335us/step - loss: 0.7971
Epoch 17/800
35/35 [==============================] - 0s 761us/step - loss: 0.7714
Epoch 18/800
35/35 [==============================] - 0s 733us/step - loss: 0.7446
Epoch 19/800
35/35 [==============================] - 0s 481us/step - loss: 0.7187
Epoch 20/800
35/35 [==============================] - 0s 689us/step - loss: 0.6883
Epoch 21/800
35/35 [==============================] - 0s 890us/step - loss: 0.6770
Epoch 22/800
35/35 [==============================] - 0s 1ms/step - loss: 0.6350
Epoch 23/800
35/35 [==============================] - 0s 934us/step - loss: 0.6041
Epoch 24/800
35/35 [==============================] - 0s 414us/step - loss: 0.5849
Epoch 25/800
35/35 [==============================] - 0s 523us/step - loss: 0.5580
Epoch 26/800
35/35 [==============================] - 0s 375us/step - loss: 0.5410
Epoch 27/800
35/35 [==============================] - 0s 492us/step - loss: 0.5121
Epoch 28/800
35/35 [==============================] - 0s 634us/step - loss: 0.5007
Epoch 29/800
35/35 [==============================] - 0s 337us/step - loss: 0.4832
Epoch 30/800
35/35 [==============================] - 0s 453us/step - loss: 0.4677
Epoch 31/800
35/35 [==============================] - 0s 327us/step - loss: 0.4487
Epoch 32/800
35/35 [==============================] - 0s 376us/step - loss: 0.4347
Epoch 33/800
35/35 [==============================] - 0s 629us/step - loss: 0.4154
Epoch 34/800
35/35 [==============================] - 0s 377us/step - loss: 0.4107
```

```
Epoch 35/800
35/35 [==============================] - 0s 740us/step - loss: 0.3890
Epoch 36/800
35/35 [==============================] - 0s 510us/step - loss: 0.3795
Epoch 37/800
35/35 [==============================] - 0s 550us/step - loss: 0.3631
Epoch 38/800
35/35 [==============================] - 0s 817us/step - loss: 0.3607
Epoch 39/800
35/35 [==============================] - 0s 507us/step - loss: 0.3372
Epoch 40/800
35/35 [==============================] - 0s 404us/step - loss: 0.3365
Epoch 41/800
35/35 [==============================] - 0s 374us/step - loss: 0.3199
Epoch 42/800
35/35 [==============================] - 0s 400us/step - loss: 0.3020
Epoch 43/800
35/35 [==============================] - 0s 686us/step - loss: 0.3093
Epoch 44/800
35/35 [==============================] - 0s 581us/step - loss: 0.3193
Epoch 45/800
35/35 [==============================] - 0s 1ms/step - loss: 0.2856
Epoch 46/800
35/35 [==============================] - ETA: 0s - loss: 0.301 - 0s 608us/step
- loss: 0.2994
Epoch 47/800
35/35 [==============================] - ETA: 0s - loss: 0.241 - 0s 753us/step
- loss: 0.2608
Epoch 48/800
35/35 [==============================] - 0s 1ms/step - loss: 0.2340
Epoch 49/800
35/35 [==============================] - 0s 429us/step - loss: 0.2402
Epoch 50/800
35/35 [==============================] - 0s 561us/step - loss: 0.2171
Epoch 51/800
35/35 [==============================] - 0s 427us/step - loss: 0.2099
Epoch 52/800
35/35 [==============================] - 0s 394us/step - loss: 0.1987
Epoch 53/800
35/35 [==============================] - 0s 414us/step - loss: 0.2075
Epoch 54/800
35/35 [==============================] - 0s 377us/step - loss: 0.2124
Epoch 55/800
35/35 [==============================] - 0s 370us/step - loss: 0.1750
Epoch 56/800
35/35 [==============================] - 0s 465us/step - loss: 0.1868
Epoch 57/800
35/35 [==============================] - 0s 461us/step - loss: 0.1634
Epoch 58/800
35/35 [==============================] - 0s 569us/step - loss: 0.1868
Epoch 59/800
35/35 [==============================] - 0s 529us/step - loss: 0.1697
Epoch 60/800
35/35 [==============================] - 0s 419us/step - loss: 0.1472
Epoch 61/800
35/35 [==============================] - 0s 892us/step - loss: 0.1458
Epoch 62/800
```

```
35/35 [==============================] - 0s 716us/step - loss: 0.1692
Epoch 63/800
35/35 [==============================] - 0s 547us/step - loss: 0.1324
Epoch 64/800
35/35 [==============================] - 0s 309us/step - loss: 0.1333
Epoch 65/800
35/35 [==============================] - 0s 813us/step - loss: 0.1190
Epoch 66/800
35/35 [==============================] - 0s 317us/step - loss: 0.1359
Epoch 67/800
35/35 [==============================] - 0s 374us/step - loss: 0.1082
Epoch 68/800
35/35 [==============================] - 0s 611us/step - loss: 0.1025
Epoch 69/800
35/35 [==============================] - 0s 387us/step - loss: 0.1006
Epoch 70/800
35/35 [==============================] - 0s 485us/step - loss: 0.0936
Epoch 71/800
35/35 [==============================] - 0s 417us/step - loss: 0.1549
Epoch 72/800
35/35 [==============================] - 0s 386us/step - loss: 0.1013
Epoch 73/800
35/35 [==============================] - 0s 477us/step - loss: 0.0889
Epoch 74/800
35/35 [==============================] - 0s 621us/step - loss: 0.1143
Epoch 75/800
35/35 [==============================] - 0s 415us/step - loss: 0.1180
Epoch 76/800
35/35 [==============================] - 0s 443us/step - loss: 0.0826
Epoch 77/800
35/35 [==============================] - 0s 320us/step - loss: 0.1356
Epoch 78/800
35/35 [==============================] - 0s 332us/step - loss: 0.1506
Epoch 79/800
35/35 [==============================] - 0s 848us/step - loss: 0.1061
Epoch 80/800
35/35 [==============================] - 0s 847us/step - loss: 0.1028
Epoch 81/800
35/35 [==============================] - 0s 954us/step - loss: 0.0688
Epoch 82/800
35/35 [==============================] - 0s 429us/step - loss: 0.0753
Epoch 83/800
35/35 [==============================] - 0s 699us/step - loss: 0.0944
Epoch 84/800
35/35 [==============================] - 0s 449us/step - loss: 0.1001
Epoch 85/800
35/35 [==============================] - 0s 501us/step - loss: 0.0801
Epoch 86/800
35/35 [==============================] - 0s 576us/step - loss: 0.0603
Epoch 87/800
35/35 [==============================] - 0s 465us/step - loss: 0.0582
Epoch 88/800
35/35 [==============================] - 0s 557us/step - loss: 0.0814
Epoch 89/800
35/35 [==============================] - 0s 302us/step - loss: 0.0684
Epoch 90/800
35/35 [==============================] - 0s 300us/step - loss: 0.0561
```

```
Epoch 91/800
35/35 [==============================] - 0s 289us/step - loss: 0.0775
Epoch 92/800
35/35 [==============================] - 0s 402us/step - loss: 0.0681
Epoch 93/800
35/35 [==============================] - 0s 334us/step - loss: 0.1113
Epoch 94/800
35/35 [==============================] - 0s 524us/step - loss: 0.0635
Epoch 95/800
35/35 [==============================] - 0s 471us/step - loss: 0.0538
Epoch 96/800
35/35 [==============================] - 0s 454us/step - loss: 0.0938
Epoch 97/800
35/35 [==============================] - 0s 326us/step - loss: 0.0533
Epoch 98/800
35/35 [==============================] - 0s 258us/step - loss: 0.0463
Epoch 99/800
35/35 [==============================] - 0s 294us/step - loss: 0.0636
Epoch 100/800
35/35 [==============================] - 0s 366us/step - loss: 0.0739
Epoch 101/800
35/35 [==============================] - 0s 356us/step - loss: 0.0458
Epoch 102/800
35/35 [==============================] - 0s 304us/step - loss: 0.0528
Epoch 103/800
35/35 [==============================] - 0s 337us/step - loss: 0.0524
Epoch 104/800
35/35 [==============================] - 0s 261us/step - loss: 0.0519
Epoch 105/800
35/35 [==============================] - 0s 303us/step - loss: 0.0778
Epoch 106/800
35/35 [==============================] - 0s 322us/step - loss: 0.0456
Epoch 107/800
35/35 [==============================] - 0s 336us/step - loss: 0.0444
Epoch 108/800
35/35 [==============================] - 0s 443us/step - loss: 0.0441
Epoch 109/800
35/35 [==============================] - 0s 562us/step - loss: 0.0575
Epoch 110/800
35/35 [==============================] - 0s 347us/step - loss: 0.0686
Epoch 111/800
35/35 [==============================] - 0s 362us/step - loss: 0.0505
Epoch 112/800
35/35 [==============================] - 0s 511us/step - loss: 0.0785
Epoch 113/800
35/35 [==============================] - 0s 331us/step - loss: 0.0564
Epoch 114/800
35/35 [==============================] - 0s 294us/step - loss: 0.0769
Epoch 115/800
35/35 [==============================] - 0s 287us/step - loss: 0.0465
Epoch 116/800
35/35 [==============================] - 0s 262us/step - loss: 0.0612
Epoch 117/800
35/35 [==============================] - 0s 328us/step - loss: 0.0588
Epoch 118/800
35/35 [==============================] - 0s 335us/step - loss: 0.0475
Epoch 119/800
```

```
35/35 [==============================] - 0s 407us/step - loss: 0.0546
Epoch 120/800
35/35 [==============================] - 0s 306us/step - loss: 0.0412
Epoch 121/800
35/35 [==============================] - 0s 249us/step - loss: 0.0400
Epoch 122/800
35/35 [==============================] - 0s 509us/step - loss: 0.0516
Epoch 123/800
35/35 [==============================] - 0s 508us/step - loss: 0.0655
Epoch 124/800
35/35 [==============================] - 0s 538us/step - loss: 0.0399
Epoch 125/800
35/35 [==============================] - 0s 615us/step - loss: 0.0374
Epoch 126/800
35/35 [==============================] - 0s 732us/step - loss: 0.0656
Epoch 127/800
35/35 [==============================] - 0s 320us/step - loss: 0.0942
Epoch 128/800
35/35 [==============================] - 0s 407us/step - loss: 0.0584
Epoch 129/800
35/35 [==============================] - 0s 536us/step - loss: 0.0455
Epoch 130/800
35/35 [==============================] - 0s 344us/step - loss: 0.0441
Epoch 131/800
35/35 [==============================] - 0s 404us/step - loss: 0.0432
Epoch 132/800
35/35 [==============================] - 0s 332us/step - loss: 0.0589
Epoch 133/800
35/35 [==============================] - 0s 381us/step - loss: 0.0839
Epoch 134/800
35/35 [==============================] - 0s 458us/step - loss: 0.0452
Epoch 135/800
35/35 [==============================] - 0s 326us/step - loss: 0.0359
Epoch 136/800
35/35 [==============================] - 0s 280us/step - loss: 0.0902
Epoch 137/800
35/35 [==============================] - 0s 277us/step - loss: 0.0536
Epoch 138/800
35/35 [==============================] - 0s 292us/step - loss: 0.0607
Epoch 139/800
35/35 [==============================] - 0s 289us/step - loss: 0.0425
Epoch 140/800
35/35 [==============================] - 0s 347us/step - loss: 0.0826
Epoch 141/800
35/35 [==============================] - 0s 336us/step - loss: 0.0368
Epoch 142/800
35/35 [==============================] - ETA: 0s - loss: 0.059 - 0s 339us/step
- loss: 0.0569
Epoch 143/800
35/35 [==============================] - 0s 565us/step - loss: 0.0489
Epoch 144/800
35/35 [==============================] - 0s 386us/step - loss: 0.0456
Epoch 145/800
35/35 [==============================] - 0s 540us/step - loss: 0.0377
Epoch 146/800
35/35 [==============================] - 0s 326us/step - loss: 0.0370
Epoch 147/800
```

```
35/35 [==============================] - 0s 572us/step - loss: 0.0426
Epoch 148/800
35/35 [==============================] - 0s 415us/step - loss: 0.0686
Epoch 149/800
35/35 [==============================] - 0s 887us/step - loss: 0.0590
Epoch 150/800
35/35 [==============================] - 0s 566us/step - loss: 0.0356
Epoch 151/800
35/35 [==============================] - 0s 748us/step - loss: 0.0390
Epoch 152/800
35/35 [==============================] - 0s 697us/step - loss: 0.0378
Epoch 153/800
35/35 [==============================] - 0s 471us/step - loss: 0.0508
Epoch 154/800
35/35 [==============================] - 0s 443us/step - loss: 0.0407
Epoch 155/800
35/35 [==============================] - 0s 681us/step - loss: 0.0608
Epoch 156/800
35/35 [==============================] - 0s 657us/step - loss: 0.0548
Epoch 157/800
35/35 [==============================] - 0s 682us/step - loss: 0.0358
Epoch 158/800
35/35 [==============================] - 0s 651us/step - loss: 0.0491
Epoch 159/800
35/35 [==============================] - 0s 924us/step - loss: 0.0606
Epoch 160/800
35/35 [==============================] - 0s 847us/step - loss: 0.0360
Epoch 161/800
35/35 [==============================] - 0s 298us/step - loss: 0.0836
Epoch 162/800
35/35 [==============================] - 0s 481us/step - loss: 0.0424
Epoch 163/800
35/35 [==============================] - 0s 317us/step - loss: 0.0501
Epoch 164/800
35/35 [==============================] - 0s 348us/step - loss: 0.0978
Epoch 165/800
35/35 [==============================] - 0s 619us/step - loss: 0.0360
Epoch 166/800
35/35 [==============================] - 0s 353us/step - loss: 0.0358
Epoch 167/800
35/35 [==============================] - 0s 368us/step - loss: 0.0417
Epoch 168/800
35/35 [==============================] - 0s 625us/step - loss: 0.0972
Epoch 169/800
35/35 [==============================] - 0s 317us/step - loss: 0.0406
Epoch 170/800
35/35 [==============================] - 0s 563us/step - loss: 0.0358
Epoch 171/800
35/35 [==============================] - 0s 557us/step - loss: 0.0428
Epoch 172/800
35/35 [==============================] - 0s 641us/step - loss: 0.0343
Epoch 173/800
35/35 [==============================] - 0s 478us/step - loss: 0.0617
Epoch 174/800
35/35 [==============================] - 0s 619us/step - loss: 0.0405
Epoch 175/800
35/35 [==============================] - 0s 429us/step - loss: 0.0720
```

```
Epoch 176/800
35/35 [==============================] - 0s 495us/step - loss: 0.0362
Epoch 177/800
35/35 [==============================] - 0s 805us/step - loss: 0.0371
Epoch 178/800
35/35 [==============================] - 0s 378us/step - loss: 0.0979
Epoch 179/800
35/35 [==============================] - 0s 402us/step - loss: 0.0484
Epoch 180/800
35/35 [==============================] - 0s 265us/step - loss: 0.0345
Epoch 181/800
35/35 [==============================] - 0s 482us/step - loss: 0.0419
Epoch 182/800
35/35 [==============================] - 0s 416us/step - loss: 0.0482
Epoch 183/800
35/35 [==============================] - 0s 431us/step - loss: 0.0399
Epoch 184/800
35/35 [==============================] - 0s 331us/step - loss: 0.0530
Epoch 185/800
35/35 [==============================] - 0s 354us/step - loss: 0.0739
Epoch 186/800
35/35 [==============================] - 0s 514us/step - loss: 0.0687
Epoch 187/800
35/35 [==============================] - 0s 335us/step - loss: 0.0369
Epoch 188/800
35/35 [==============================] - 0s 279us/step - loss: 0.0421
Epoch 189/800
35/35 [==============================] - 0s 311us/step - loss: 0.0831
Epoch 190/800
35/35 [==============================] - 0s 398us/step - loss: 0.0348
Epoch 191/800
35/35 [==============================] - 0s 365us/step - loss: 0.0776
Epoch 192/800
35/35 [==============================] - 0s 327us/step - loss: 0.0682
Epoch 193/800
35/35 [==============================] - 0s 408us/step - loss: 0.0602
Epoch 194/800
35/35 [==============================] - 0s 280us/step - loss: 0.0514
Epoch 195/800
35/35 [==============================] - 0s 309us/step - loss: 0.0508
Epoch 196/800
35/35 [==============================] - 0s 281us/step - loss: 0.0690
Epoch 197/800
35/35 [==============================] - 0s 358us/step - loss: 0.0462
Epoch 198/800
35/35 [==============================] - 0s 288us/step - loss: 0.0523
Epoch 199/800
35/35 [==============================] - 0s 341us/step - loss: 0.0554
Epoch 200/800
35/35 [==============================] - 0s 349us/step - loss: 0.0385
Epoch 201/800
35/35 [==============================] - 0s 300us/step - loss: 0.0447
Epoch 202/800
35/35 [==============================] - 0s 417us/step - loss: 0.0514
Epoch 203/800
35/35 [==============================] - 0s 514us/step - loss: 0.0534
Epoch 204/800
```

```
35/35 [==============================] - 0s 339us/step - loss: 0.0386
Epoch 205/800
35/35 [==============================] - 0s 309us/step - loss: 0.0402
Epoch 206/800
35/35 [==============================] - 0s 411us/step - loss: 0.0420
Epoch 207/800
35/35 [==============================] - 0s 354us/step - loss: 0.0409
Epoch 208/800
35/35 [==============================] - 0s 323us/step - loss: 0.0385
Epoch 209/800
35/35 [==============================] - 0s 296us/step - loss: 0.0447
Epoch 210/800
35/35 [==============================] - 0s 354us/step - loss: 0.0562
Epoch 211/800
35/35 [==============================] - 0s 332us/step - loss: 0.0381
Epoch 212/800
35/35 [==============================] - 0s 355us/step - loss: 0.0777
Epoch 213/800
35/35 [==============================] - 0s 306us/step - loss: 0.0370
Epoch 214/800
35/35 [==============================] - 0s 353us/step - loss: 0.0332
Epoch 215/800
35/35 [==============================] - 0s 508us/step - loss: 0.0388
Epoch 216/800
35/35 [==============================] - 0s 342us/step - loss: 0.0667
Epoch 217/800
35/35 [==============================] - 0s 402us/step - loss: 0.0527
Epoch 218/800
35/35 [==============================] - 0s 429us/step - loss: 0.0395
Epoch 219/800
35/35 [==============================] - 0s 807us/step - loss: 0.0481
Epoch 220/800
35/35 [==============================] - 0s 873us/step - loss: 0.0332
Epoch 221/800
35/35 [==============================] - 0s 652us/step - loss: 0.0498
Epoch 222/800
35/35 [==============================] - 0s 513us/step - loss: 0.0405
Epoch 223/800
35/35 [==============================] - 0s 791us/step - loss: 0.0610
Epoch 224/800
35/35 [==============================] - 0s 441us/step - loss: 0.0390
Epoch 225/800
35/35 [==============================] - 0s 363us/step - loss: 0.0576
Epoch 226/800
35/35 [==============================] - 0s 264us/step - loss: 0.0389
Epoch 227/800
35/35 [==============================] - 0s 289us/step - loss: 0.0634
Epoch 228/800
35/35 [==============================] - 0s 388us/step - loss: 0.0343
Epoch 229/800
35/35 [==============================] - 0s 309us/step - loss: 0.0802
Epoch 230/800
35/35 [==============================] - 0s 376us/step - loss: 0.0348
Epoch 231/800
35/35 [==============================] - 0s 315us/step - loss: 0.0338
Epoch 232/800
35/35 [==============================] - 0s 472us/step - loss: 0.0372
```

```
Epoch 233/800
35/35 [==============================] - 0s 636us/step - loss: 0.0782
Epoch 234/800
35/35 [==============================] - 0s 558us/step - loss: 0.0768
Epoch 235/800
35/35 [==============================] - 0s 522us/step - loss: 0.0336
Epoch 236/800
35/35 [==============================] - 0s 271us/step - loss: 0.0413
Epoch 237/800
35/35 [==============================] - 0s 261us/step - loss: 0.0345
Epoch 238/800
35/35 [==============================] - 0s 398us/step - loss: 0.0402
Epoch 239/800
35/35 [==============================] - 0s 315us/step - loss: 0.0373
Epoch 240/800
35/35 [==============================] - 0s 317us/step - loss: 0.0373
Epoch 241/800
35/35 [==============================] - 0s 300us/step - loss: 0.0579
Epoch 242/800
35/35 [==============================] - 0s 251us/step - loss: 0.0642
Epoch 243/800
35/35 [==============================] - 0s 244us/step - loss: 0.0346
Epoch 244/800
35/35 [==============================] - 0s 237us/step - loss: 0.0783
Epoch 245/800
35/35 [==============================] - 0s 253us/step - loss: 0.0353
Epoch 246/800
35/35 [==============================] - 0s 265us/step - loss: 0.0348
Epoch 247/800
35/35 [==============================] - 0s 254us/step - loss: 0.0408
Epoch 248/800
35/35 [==============================] - 0s 312us/step - loss: 0.0610
Epoch 249/800
35/35 [==============================] - 0s 325us/step - loss: 0.0394
Epoch 250/800
35/35 [==============================] - 0s 325us/step - loss: 0.0629
Epoch 251/800
35/35 [==============================] - 0s 308us/step - loss: 0.0350
Epoch 252/800
35/35 [==============================] - 0s 278us/step - loss: 0.0372
Epoch 253/800
35/35 [==============================] - 0s 338us/step - loss: 0.0482
Epoch 254/800
35/35 [==============================] - 0s 343us/step - loss: 0.0352
Epoch 255/800
35/35 [==============================] - 0s 373us/step - loss: 0.0399
Epoch 256/800
35/35 [==============================] - 0s 458us/step - loss: 0.0331
Epoch 257/800
35/35 [==============================] - 0s 272us/step - loss: 0.0481
Epoch 258/800
35/35 [==============================] - 0s 333us/step - loss: 0.0603
Epoch 259/800
35/35 [==============================] - 0s 449us/step - loss: 0.0428
Epoch 260/800
35/35 [==============================] - 0s 830us/step - loss: 0.0729
Epoch 261/800
```

```
35/35 [==============================] - 0s 793us/step - loss: 0.0506
Epoch 262/800
35/35 [==============================] - 0s 827us/step - loss: 0.0448
Epoch 263/800
35/35 [==============================] - 0s 525us/step - loss: 0.0392
Epoch 264/800
35/35 [==============================] - 0s 441us/step - loss: 0.0683
Epoch 265/800
35/35 [==============================] - 0s 353us/step - loss: 0.0385
Epoch 266/800
35/35 [==============================] - 0s 438us/step - loss: 0.0679
Epoch 267/800
35/35 [==============================] - 0s 436us/step - loss: 0.0341
Epoch 268/800
35/35 [==============================] - 0s 332us/step - loss: 0.0326
Epoch 269/800
35/35 [==============================] - 0s 401us/step - loss: 0.0459
Epoch 270/800
35/35 [==============================] - 0s 563us/step - loss: 0.0338
Epoch 271/800
35/35 [==============================] - 0s 353us/step - loss: 0.0374
Epoch 272/800
35/35 [==============================] - 0s 353us/step - loss: 0.0570
Epoch 273/800
35/35 [==============================] - 0s 282us/step - loss: 0.0345
Epoch 274/800
35/35 [==============================] - 0s 257us/step - loss: 0.0430
Epoch 275/800
35/35 [==============================] - 0s 386us/step - loss: 0.0599
Epoch 276/800
35/35 [==============================] - 0s 1ms/step - loss: 0.0327
Epoch 277/800
35/35 [==============================] - 0s 467us/step - loss: 0.0369
Epoch 278/800
35/35 [==============================] - 0s 508us/step - loss: 0.0540
Epoch 279/800
35/35 [==============================] - 0s 308us/step - loss: 0.0408
Epoch 280/800
35/35 [==============================] - 0s 408us/step - loss: 0.0314
Epoch 281/800
35/35 [==============================] - 0s 282us/step - loss: 0.0649
Epoch 282/800
35/35 [==============================] - 0s 349us/step - loss: 0.0382
Epoch 283/800
35/35 [==============================] - 0s 277us/step - loss: 0.0330
Epoch 284/800
35/35 [==============================] - 0s 294us/step - loss: 0.0318
Epoch 285/800
35/35 [==============================] - 0s 321us/step - loss: 0.0712
Epoch 286/800
35/35 [==============================] - 0s 414us/step - loss: 0.0408
Epoch 287/800
35/35 [==============================] - 0s 458us/step - loss: 0.0687
Epoch 288/800
35/35 [==============================] - 0s 363us/step - loss: 0.0371
Epoch 289/800
35/35 [==============================] - 0s 406us/step - loss: 0.0440
```

```
Epoch 290/800
35/35 [==============================] - 0s 328us/step - loss: 0.0340
Epoch 291/800
35/35 [==============================] - 0s 431us/step - loss: 0.0330
Epoch 292/800
35/35 [==============================] - 0s 345us/step - loss: 0.0641
Epoch 293/800
35/35 [==============================] - 0s 305us/step - loss: 0.0638
Epoch 294/800
35/35 [==============================] - 0s 330us/step - loss: 0.0326
Epoch 295/800
35/35 [==============================] - 0s 447us/step - loss: 0.0349
Epoch 296/800
35/35 [==============================] - 0s 469us/step - loss: 0.0519
Epoch 297/800
35/35 [==============================] - 0s 357us/step - loss: 0.0468
Epoch 298/800
35/35 [==============================] - 0s 331us/step - loss: 0.0318
Epoch 299/800
35/35 [==============================] - 0s 341us/step - loss: 0.0351
Epoch 300/800
35/35 [==============================] - 0s 334us/step - loss: 0.0618
Epoch 301/800
35/35 [==============================] - 0s 389us/step - loss: 0.0379
Epoch 302/800
35/35 [==============================] - 0s 318us/step - loss: 0.0696
Epoch 303/800
35/35 [==============================] - 0s 604us/step - loss: 0.0345
Epoch 304/800
35/35 [==============================] - 0s 431us/step - loss: 0.0393
Epoch 305/800
35/35 [==============================] - 0s 422us/step - loss: 0.0612
Epoch 306/800
35/35 [==============================] - 0s 465us/step - loss: 0.0390
Epoch 307/800
35/35 [==============================] - 0s 439us/step - loss: 0.0545
Epoch 308/800
35/35 [==============================] - 0s 692us/step - loss: 0.0526
Epoch 309/800
35/35 [==============================] - 0s 418us/step - loss: 0.0380
Epoch 310/800
35/35 [==============================] - 0s 653us/step - loss: 0.0329
Epoch 311/800
35/35 [==============================] - 0s 533us/step - loss: 0.0534
Epoch 312/800
35/35 [==============================] - 0s 356us/step - loss: 0.0588
Epoch 313/800
35/35 [==============================] - 0s 400us/step - loss: 0.0351
Epoch 314/800
35/35 [==============================] - 0s 309us/step - loss: 0.0511
Epoch 315/800
35/35 [==============================] - 0s 411us/step - loss: 0.0314
Epoch 316/800
35/35 [==============================] - 0s 313us/step - loss: 0.0324
Epoch 317/800
35/35 [==============================] - 0s 550us/step - loss: 0.0483
Epoch 318/800
```

```
35/35 [==============================] - 0s 360us/step - loss: 0.0530
Epoch 319/800
35/35 [==============================] - 0s 339us/step - loss: 0.0377
Epoch 320/800
35/35 [==============================] - 0s 331us/step - loss: 0.0327
Epoch 321/800
35/35 [==============================] - 0s 394us/step - loss: 0.0568
Epoch 322/800
35/35 [==============================] - 0s 440us/step - loss: 0.0437
Epoch 323/800
35/35 [==============================] - 0s 403us/step - loss: 0.0499
Epoch 324/800
35/35 [==============================] - 0s 340us/step - loss: 0.0329
Epoch 325/800
35/35 [==============================] - 0s 252us/step - loss: 0.0468
Epoch 326/800
35/35 [==============================] - 0s 262us/step - loss: 0.0545
Epoch 327/800
35/35 [==============================] - 0s 287us/step - loss: 0.0579
Epoch 328/800
35/35 [==============================] - 0s 469us/step - loss: 0.0343
Epoch 329/800
35/35 [==============================] - 0s 399us/step - loss: 0.0498
Epoch 330/800
35/35 [==============================] - 0s 350us/step - loss: 0.0362
Epoch 331/800
35/35 [==============================] - 0s 423us/step - loss: 0.0389
Epoch 332/800
35/35 [==============================] - 0s 345us/step - loss: 0.0657
Epoch 333/800
35/35 [==============================] - 0s 368us/step - loss: 0.0737
Epoch 334/800
35/35 [==============================] - 0s 620us/step - loss: 0.0308
Epoch 335/800
35/35 [==============================] - 0s 257us/step - loss: 0.0314
Epoch 336/800
35/35 [==============================] - 0s 301us/step - loss: 0.0671
Epoch 337/800
35/35 [==============================] - 0s 400us/step - loss: 0.0354
Epoch 338/800
35/35 [==============================] - 0s 258us/step - loss: 0.0330
Epoch 339/800
35/35 [==============================] - 0s 285us/step - loss: 0.0486
Epoch 340/800
35/35 [==============================] - 0s 322us/step - loss: 0.0306
Epoch 341/800
35/35 [==============================] - 0s 256us/step - loss: 0.0731
Epoch 342/800
35/35 [==============================] - 0s 289us/step - loss: 0.0338
Epoch 343/800
35/35 [==============================] - 0s 328us/step - loss: 0.0623
Epoch 344/800
35/35 [==============================] - 0s 351us/step - loss: 0.0551
Epoch 345/800
35/35 [==============================] - 0s 362us/step - loss: 0.0509
Epoch 346/800
35/35 [==============================] - 0s 384us/step - loss: 0.0335
```

```
Epoch 347/800
35/35 [==============================] - 0s 495us/step - loss: 0.0335
Epoch 348/800
35/35 [==============================] - ETA: 0s - loss: 0.045 - 0s 318us/step
- loss: 0.0467
Epoch 349/800
35/35 [==============================] - 0s 488us/step - loss: 0.0513
Epoch 350/800
35/35 [==============================] - 0s 457us/step - loss: 0.0545
Epoch 351/800
35/35 [==============================] - 0s 314us/step - loss: 0.0325
Epoch 352/800
35/35 [==============================] - 0s 319us/step - loss: 0.0437
Epoch 353/800
35/35 [==============================] - 0s 401us/step - loss: 0.0339
Epoch 354/800
35/35 [==============================] - 0s 405us/step - loss: 0.0413
Epoch 355/800
35/35 [==============================] - 0s 311us/step - loss: 0.0343
Epoch 356/800
35/35 [==============================] - 0s 309us/step - loss: 0.0316
Epoch 357/800
35/35 [==============================] - 0s 284us/step - loss: 0.0449
Epoch 358/800
35/35 [==============================] - 0s 282us/step - loss: 0.0522
Epoch 359/800
35/35 [==============================] - 0s 280us/step - loss: 0.0362
Epoch 360/800
35/35 [==============================] - 0s 693us/step - loss: 0.0319
Epoch 361/800
35/35 [==============================] - 0s 545us/step - loss: 0.0315
Epoch 362/800
35/35 [==============================] - 0s 643us/step - loss: 0.0482
Epoch 363/800
35/35 [==============================] - 0s 594us/step - loss: 0.0618
Epoch 364/800
35/35 [==============================] - 0s 676us/step - loss: 0.0368
Epoch 365/800
35/35 [==============================] - 0s 382us/step - loss: 0.0684
Epoch 366/800
35/35 [==============================] - 0s 306us/step - loss: 0.0446
Epoch 367/800
35/35 [==============================] - 0s 358us/step - loss: 0.0329
Epoch 368/800
35/35 [==============================] - 0s 283us/step - loss: 0.0440
Epoch 369/800
35/35 [==============================] - 0s 271us/step - loss: 0.0459
Epoch 370/800
35/35 [==============================] - 0s 311us/step - loss: 0.0573
Epoch 371/800
35/35 [==============================] - 0s 443us/step - loss: 0.0341
Epoch 372/800
35/35 [==============================] - 0s 279us/step - loss: 0.0374
Epoch 373/800
35/35 [==============================] - 0s 346us/step - loss: 0.0402
Epoch 374/800
35/35 [==============================] - 0s 331us/step - loss: 0.0563
```

```
Epoch 375/800
35/35 [==============================] - 0s 311us/step - loss: 0.0369
Epoch 376/800
35/35 [==============================] - 0s 262us/step - loss: 0.0521
Epoch 377/800
35/35 [==============================] - 0s 266us/step - loss: 0.0312
Epoch 378/800
35/35 [==============================] - 0s 368us/step - loss: 0.0617
Epoch 379/800
35/35 [==============================] - 0s 351us/step - loss: 0.0395
Epoch 380/800
35/35 [==============================] - 0s 289us/step - loss: 0.0324
Epoch 381/800
35/35 [==============================] - 0s 343us/step - loss: 0.0314
Epoch 382/800
35/35 [==============================] - 0s 458us/step - loss: 0.0419
Epoch 383/800
35/35 [==============================] - 0s 266us/step - loss: 0.0432
Epoch 384/800
35/35 [==============================] - 0s 279us/step - loss: 0.0338
Epoch 385/800
35/35 [==============================] - 0s 251us/step - loss: 0.0417
Epoch 386/800
35/35 [==============================] - 0s 324us/step - loss: 0.0301
Epoch 387/800
35/35 [==============================] - 0s 251us/step - loss: 0.0376
Epoch 388/800
35/35 [==============================] - 0s 386us/step - loss: 0.0486
Epoch 389/800
35/35 [==============================] - 0s 344us/step - loss: 0.0345
Epoch 390/800
35/35 [==============================] - 0s 303us/step - loss: 0.0390
Epoch 391/800
35/35 [==============================] - 0s 292us/step - loss: 0.0530
Epoch 392/800
35/35 [==============================] - 0s 653us/step - loss: 0.0307
Epoch 393/800
35/35 [==============================] - 0s 700us/step - loss: 0.0425
Epoch 394/800
35/35 [==============================] - 0s 541us/step - loss: 0.0311
Epoch 395/800
35/35 [==============================] - 0s 2ms/step - loss: 0.0369
Epoch 396/800
35/35 [==============================] - 0s 598us/step - loss: 0.0585
Epoch 397/800
35/35 [==============================] - 0s 433us/step - loss: 0.0345
Epoch 398/800
35/35 [==============================] - 0s 310us/step - loss: 0.0330
Epoch 399/800
35/35 [==============================] - 0s 414us/step - loss: 0.0324
Epoch 400/800
35/35 [==============================] - 0s 533us/step - loss: 0.0505
Epoch 401/800
35/35 [==============================] - 0s 466us/step - loss: 0.0326
Epoch 402/800
35/35 [==============================] - 0s 421us/step - loss: 0.0638
Epoch 403/800
```

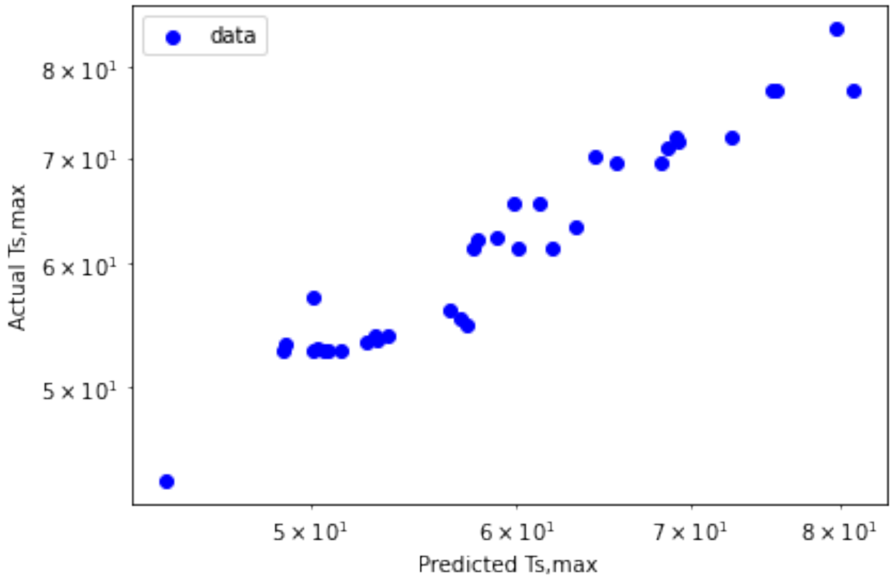
```
35/35 [==============================] - 0s 360us/step - loss: 0.0331
Epoch 404/800
35/35 [==============================] - 0s 441us/step - loss: 0.0487
Epoch 405/800
35/35 [==============================] - 0s 390us/step - loss: 0.0312
Epoch 406/800
35/35 [==============================] - 0s 546us/step - loss: 0.0381
Epoch 407/800
35/35 [==============================] - 0s 578us/step - loss: 0.0480
Epoch 408/800
35/35 [==============================] - 0s 317us/step - loss: 0.0547
Epoch 409/800
35/35 [==============================] - 0s 404us/step - loss: 0.0652
Epoch 410/800
35/35 [==============================] - 0s 362us/step - loss: 0.0431
Epoch 411/800
35/35 [==============================] - 0s 314us/step - loss: 0.0352
Epoch 412/800
35/35 [==============================] - 0s 404us/step - loss: 0.0580
Epoch 413/800
35/35 [==============================] - 0s 319us/step - loss: 0.0355
Epoch 414/800
35/35 [==============================] - 0s 392us/step - loss: 0.0314
Epoch 415/800
35/35 [==============================] - 0s 624us/step - loss: 0.0598
Epoch 416/800
35/35 [==============================] - 0s 334us/step - loss: 0.0528
Epoch 417/800
35/35 [==============================] - 0s 423us/step - loss: 0.0388
Epoch 418/800
35/35 [==============================] - 0s 550us/step - loss: 0.0515
Epoch 419/800
35/35 [==============================] - 0s 504us/step - loss: 0.0518
Epoch 420/800
35/35 [==============================] - 0s 294us/step - loss: 0.0339
Epoch 421/800
35/35 [==============================] - 0s 276us/step - loss: 0.0555
Epoch 422/800
35/35 [==============================] - 0s 316us/step - loss: 0.0317
Epoch 423/800
35/35 [==============================] - 0s 310us/step - loss: 0.0340
Epoch 424/800
35/35 [==============================] - 0s 289us/step - loss: 0.0384
Epoch 425/800
35/35 [==============================] - 0s 272us/step - loss: 0.0309
Epoch 426/800
35/35 [==============================] - 0s 313us/step - loss: 0.0408
Epoch 427/800
35/35 [==============================] - 0s 262us/step - loss: 0.0316
Epoch 428/800
35/35 [==============================] - 0s 272us/step - loss: 0.0474
Epoch 429/800
35/35 [==============================] - 0s 384us/step - loss: 0.0320
Epoch 430/800
35/35 [==============================] - 0s 377us/step - loss: 0.0297
Epoch 431/800
35/35 [==============================] - 0s 280us/step - loss: 0.0407
```

```
Epoch 432/800
35/35 [==============================] - 0s 277us/step - loss: 0.0331
Epoch 433/800
35/35 [==============================] - 0s 280us/step - loss: 0.0366
Epoch 434/800
35/35 [==============================] - 0s 256us/step - loss: 0.0594
Epoch 435/800
35/35 [==============================] - 0s 248us/step - loss: 0.0366
Epoch 436/800
35/35 [==============================] - 0s 287us/step - loss: 0.0476
Epoch 437/800
35/35 [==============================] - 0s 407us/step - loss: 0.0352
Epoch 438/800
35/35 [==============================] - 0s 423us/step - loss: 0.0380
Epoch 439/800
35/35 [==============================] - 0s 465us/step - loss: 0.0316
Epoch 440/800
35/35 [==============================] - 0s 339us/step - loss: 0.0355
Epoch 441/800
35/35 [==============================] - 0s 343us/step - loss: 0.0778
Epoch 442/800
35/35 [==============================] - 0s 309us/step - loss: 0.0525
Epoch 443/800
35/35 [==============================] - 0s 291us/step - loss: 0.0357
Epoch 444/800
35/35 [==============================] - 0s 283us/step - loss: 0.0543
Epoch 445/800
35/35 [==============================] - 0s 252us/step - loss: 0.0338
Epoch 446/800
35/35 [==============================] - 0s 286us/step - loss: 0.0576
Epoch 447/800
35/35 [==============================] - 0s 295us/step - loss: 0.0519
Epoch 448/800
35/35 [==============================] - 0s 295us/step - loss: 0.0391
Epoch 449/800
35/35 [==============================] - 0s 461us/step - loss: 0.0305
Epoch 450/800
35/35 [==============================] - 0s 439us/step - loss: 0.0346
Epoch 451/800
35/35 [==============================] - 0s 319us/step - loss: 0.0381
Epoch 452/800
35/35 [==============================] - 0s 310us/step - loss: 0.0691
Epoch 453/800
35/35 [==============================] - 0s 273us/step - loss: 0.0449
Epoch 454/800
35/35 [==============================] - 0s 313us/step - loss: 0.0388
Epoch 455/800
35/35 [==============================] - 0s 344us/step - loss: 0.0553
Epoch 456/800
35/35 [==============================] - 0s 326us/step - loss: 0.0350
Epoch 457/800
35/35 [==============================] - 0s 283us/step - loss: 0.0347
Epoch 458/800
35/35 [==============================] - 0s 256us/step - loss: 0.0326
Epoch 459/800
35/35 [==============================] - 0s 319us/step - loss: 0.0305
Epoch 460/800
```

```
35/35 [==============================] - 0s 674us/step - loss: 0.0784
Epoch 461/800
35/35 [==============================] - 0s 340us/step - loss: 0.0439
Epoch 462/800
35/35 [==============================] - 0s 290us/step - loss: 0.0542
Epoch 463/800
35/35 [==============================] - 0s 374us/step - loss: 0.0392
Epoch 464/800
35/35 [==============================] - 0s 277us/step - loss: 0.0526
Epoch 465/800
35/35 [==============================] - 0s 418us/step - loss: 0.0574
Epoch 466/800
35/35 [==============================] - 0s 315us/step - loss: 0.0326
Epoch 467/800
35/35 [==============================] - 0s 299us/step - loss: 0.0311
Epoch 468/800
35/35 [==============================] - 0s 263us/step - loss: 0.0321
Epoch 469/800
35/35 [==============================] - 0s 324us/step - loss: 0.0451
Epoch 470/800
35/35 [==============================] - 0s 273us/step - loss: 0.0433
Epoch 471/800
35/35 [==============================] - 0s 490us/step - loss: 0.0332
Epoch 472/800
35/35 [==============================] - 0s 302us/step - loss: 0.0372
Epoch 473/800
35/35 [==============================] - 0s 314us/step - loss: 0.0312
Epoch 474/800
35/35 [==============================] - 0s 305us/step - loss: 0.0613
Epoch 475/800
35/35 [==============================] - 0s 314us/step - loss: 0.0554
Epoch 476/800
35/35 [==============================] - 0s 305us/step - loss: 0.0320
Epoch 477/800
35/35 [==============================] - 0s 289us/step - loss: 0.0577
Epoch 478/800
35/35 [==============================] - 0s 470us/step - loss: 0.0357
Epoch 479/800
35/35 [==============================] - 0s 511us/step - loss: 0.0484
Epoch 480/800
35/35 [==============================] - 0s 354us/step - loss: 0.0357
Epoch 481/800
35/35 [==============================] - 0s 298us/step - loss: 0.0368
Epoch 482/800
35/35 [==============================] - 0s 298us/step - loss: 0.0367
Epoch 483/800
35/35 [==============================] - 0s 341us/step - loss: 0.0372
Epoch 484/800
35/35 [==============================] - 0s 312us/step - loss: 0.0405
Epoch 485/800
35/35 [==============================] - 0s 448us/step - loss: 0.0316
Epoch 486/800
35/35 [==============================] - 0s 307us/step - loss: 0.0442
Epoch 487/800
35/35 [==============================] - 0s 357us/step - loss: 0.0480
Epoch 488/800
35/35 [==============================] - 0s 331us/step - loss: 0.0392
```

```
Epoch 489/800
35/35 [==============================] - 0s 273us/step - loss: 0.0452
Epoch 490/800
35/35 [==============================] - 0s 305us/step - loss: 0.0432
Epoch 491/800
35/35 [==============================] - 0s 321us/step - loss: 0.0310
Epoch 492/800
35/35 [==============================] - 0s 307us/step - loss: 0.0593
Epoch 493/800
35/35 [==============================] - 0s 316us/step - loss: 0.0298
Epoch 494/800
35/35 [==============================] - 0s 310us/step - loss: 0.0313
Epoch 495/800
35/35 [==============================] - 0s 326us/step - loss: 0.0337
Epoch 496/800
35/35 [==============================] - 0s 286us/step - loss: 0.0391
Epoch 497/800
35/35 [==============================] - 0s 488us/step - loss: 0.0483
Epoch 498/800
35/35 [==============================] - 0s 275us/step - loss: 0.0315
Epoch 499/800
35/35 [==============================] - 0s 289us/step - loss: 0.0349
Epoch 500/800
35/35 [==============================] - 0s 329us/step - loss: 0.0309
Epoch 501/800
35/35 [==============================] - 0s 410us/step - loss: 0.0300
Epoch 502/800
35/35 [==============================] - 0s 388us/step - loss: 0.0309
Epoch 503/800
35/35 [==============================] - 0s 259us/step - loss: 0.0429
Epoch 504/800
35/35 [==============================] - 0s 315us/step - loss: 0.0548
Epoch 505/800
35/35 [==============================] - 0s 257us/step - loss: 0.0599
Epoch 506/800
35/35 [==============================] - 0s 310us/step - loss: 0.0385
Epoch 507/800
35/35 [==============================] - 0s 519us/step - loss: 0.0550
Epoch 508/800
35/35 [==============================] - 0s 446us/step - loss: 0.0323
Epoch 509/800
35/35 [==============================] - 0s 357us/step - loss: 0.0603
Epoch 510/800
35/35 [==============================] - 0s 339us/step - loss: 0.0436
Restoring model weights from the end of the best epoch
Epoch 00510: early stopping
best epoch =  430
smallest loss = 0.029722268134355544
```

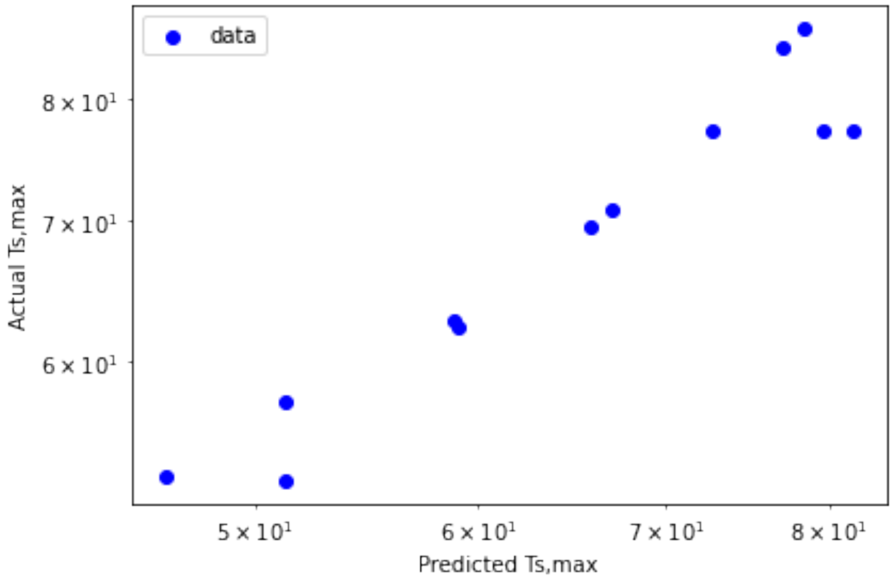
In [12]:
```
# Task 2.1e
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model4 = keras.models.load_model("best_modelv4")

import matplotlib.pyplot as plt

Tspred = []

for i in range(len(X_train4)):
    test4 = [[X_train4[i][0], X_train4[i][1], X_train4[i][2]]]
    testarray4 = np.array(test4)
    a4 = recon_model4.predict(testarray4)
    Tspred.append([a4[0][0]*medTs])

Tsorig = y_train4*medTs

plt.figure()
ax = plt.gca()
ax.scatter(Tspred ,Tsorig , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.xlabel("Predicted Ts,max")
plt.ylabel("Actual Ts,max")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_Ts = metrics.mean_absolute_error(Tspred/medTs,Tsorig/medTs)
print('mean absolute error between predictions and the collection of test dat
```




```
mean absolute error between predictions and the collection of test data: Ts,ma
x = 0.040753101902814O7
```

In [13]:

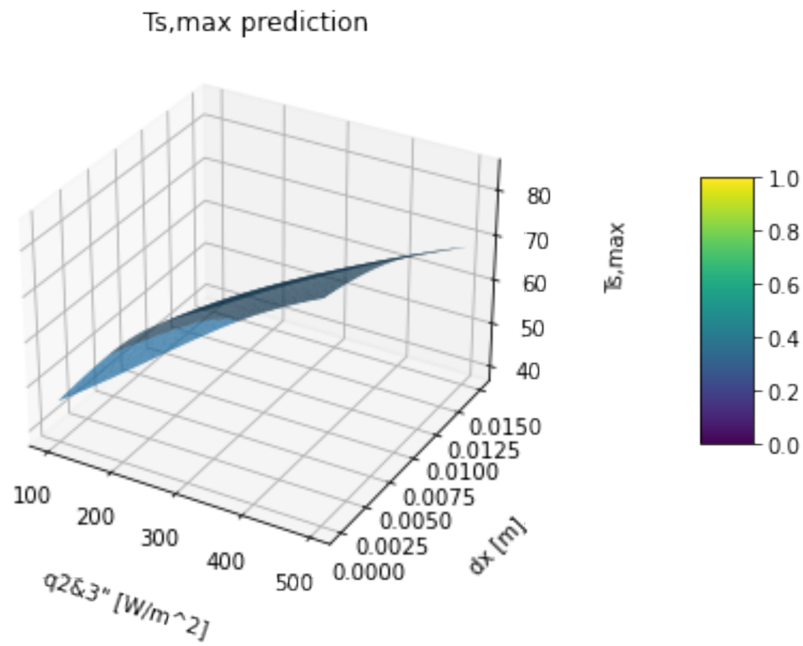
```
# Task 2.1f
from sklearn import metrics

# This line of code can be used to reconstruct the saved model. The name of t
recon_model4 = keras.models.load_model("best_modelv4")

import matplotlib.pyplot as plt

Tspred2 = []

for i in range(len(X_test4)):
    testv4 = [[X_test4[i][0], X_test4[i][1], X_test4[i][2]]]
    testarrayv4 = np.array(testv4)
    at4 = recon_model4.predict(testarrayv4)
    Tspred2.append([at4[0][0]*medTs])

Tsorig2 = y_test4*medTs

plt.figure()
ax = plt.gca()
ax.scatter(Tspred2 ,Tsorig2 , c='blue', label = 'data')
ax.set_yscale('log')
ax.set_xscale('log')
plt.xlabel("Predicted Ts,max")
plt.ylabel("Actual Ts,max")
plt.legend()
plt.tight_layout()
plt.show()

#MAE of predicted vs test data
mae_Ts2 = metrics.mean_absolute_error(Tspred2/medTs,Tsorig2/medTs)
print('mean absolute error between predictions and the collection of test dat
```




```
mean absolute error between predictions and the collection of test data: Ts,ma
x = 0.07453766947518334
```

In [11]:

```
#Task2.1g

X = np.linspace(100, 500) #q23
Y = np.linspace(0.0, 0.015) #dx

testdatap4 = []
Ts4= [] #output
preddatap4 = []

Xn = X/medq1
q2 = X/medq2
Yn = Y/meddx

for x in range(len(Xn)):
    for y in range(len(Yn)):
        testdatap4.append([Xn[x], q2[x], Yn[y]])

Xp = np.asarray(testdatap4)[:,0]*medq1
q2p = np.asarray(testdatap4)[:,1]*medq2
Yp = np.asarray(testdatap4)[:,2]*meddx

for x in range(len(testdatap4)):
    testp4 = [[testdatap4[x][0], testdatap4[x][1], testdatap4[x][2]]]
    testarrayp4 = np.array(testp4)
    outptp4 = recon_model4.predict(testarrayp4)
    preddatap4.append(outptp4)
    Ts4.append(outptp4[0][0]*medTs)

fig = plt.figure()
ax = plt.axes(projection='3d')
surf = ax.plot_trisurf(Xp, Yp, Ts4)
fig.colorbar(surf, shrink=0.5, aspect=5, pad=0.2)
ax.set_zlabel('Ts,max', rotation=60)
ax.set_ylabel('dx [m]')
ax.set_xlabel('q2&3" [W/m^2]', rotation=150)
ax.xaxis.labelpad=15
ax.yaxis.labelpad=15
ax.zaxis.labelpad=15
ax.title.set_text('Ts,max prediction');
plt.tight_layout()
plt.show()
```


Ts,max prediction
80
70
60
50
40
Ts,max
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
dx [m]
100
200
300
400
500
q2&3" [W/m^2]
1.0
0.8
0.6
0.4
0.2
0.0