2020_1124_ANN_Modeling

November 25, 2020

1 Predicting Concrete Compressive Strength - Artificial Neural Network (ANN) Modeling in TensorFlow 2.0

In this code notebook, we will import the data, scale it, perform a train-test split, and run it through various artificial neural network (ANN) configurations in TensorFlow 2.0 using Keras.

1.1 Dataset Citation

This dataset was retrieved from the UC Irvine Machine Learning Repository from the following URL: https://archive.ics.uci.edu/ml/datasets/Concrete+Compressive+Strength.

The dataset was donated to the UCI Repository by Prof. I-Cheng Yeh of Chung-Huah University, who retains copyright for the following published paper: I-Cheng Yeh, "Modeling of strength of high performance concrete using artificial neural networks," Cement and Concrete Research, Vol. 28, No. 12, pp. 1797-1808 (1998). Additional papers citing this dataset are listed at the reference link above.

1.2 Import the Relevant Libraries

[2]:
```
# Data Manipulation
import numpy as np
import pandas as pd

# Data Visualization
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
sns.set()

# Data Preprocessing
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import MinMaxScaler

# ANN Modeling in TensorFlow & Keras
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation
from tensorflow.keras.optimizers import Adam
```

```
from tensorflow.keras.layers import Dropout

# Model Evaluation
from sklearn.metrics import␣
↪mean_squared_error,mean_absolute_error,explained_variance_score
```

1.3 Data Preprocessing

1.3.1 Import & Check the Data

[3]:
```
df = pd.read_csv('2020_1124_Modeling_Data.csv')
concrete_data = df.copy()
```

[4]:
```
concrete_data.head()
```

[4]:
```
   Cement  Blast_Furnace_Slag  Fly_Ash  Water  Superplasticizer  \
0   540.0                 0.0      0.0  162.0               2.5
1   540.0                 0.0      0.0  162.0               2.5
2   332.5               142.5      0.0  228.0               0.0
3   332.5               142.5      0.0  228.0               0.0
4   198.6               132.4      0.0  192.0               0.0

   Coarse_Aggregate  Fine_Aggregate  Age  Compressive_Strength
0            1040.0           676.0   28                 79.99
1            1055.0           676.0   28                 61.89
2             932.0           594.0  270                 40.27
3             932.0           594.0  365                 41.05
4             978.4           825.5  360                 44.30
```

1.3.2 Train Test Split

[12]:
```
X = concrete_data.drop('Compressive_Strength',axis=1)
y = concrete_data['Compressive_Strength']
```

[15]:
```
X_train, X_test, y_train, y_test = train_test_split(X,y,test_size=0.
↪2,random_state=42)
```

1.3.3 Scale the Data

[16]:
```
scaler = MinMaxScaler()
X_train= scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)
```

1.4 Model 1 - ANN with 3 Hidden Layers

1.4.1 Construct the Artificial Neural Network

[19]:
```
# Determine number of starting nodes by finding the shape of X_train
X_train.shape
```

[19]: (824, 8)

[20]:
```
model = Sequential()

# We will start with 2 hidden layers.
model.add(Dense(8,activation='relu')) # All layers utilize rectified linear␣
↪units (relu)
model.add(Dense(8,activation='relu'))
model.add(Dense(8,activation='relu'))
model.add(Dense(8,activation='relu'))
model.add(Dense(1))

model.compile(optimizer='adam',loss='mse') # Use the adam optimization algorithm
```

1.4.2 Train the Model on the Test Data

[21]:
```
model.fit(x=X_train,y=y_train.values,
          validation_data=(X_test,y_test.values),
          batch_size=128,epochs=400)
```

```
Epoch 1/400
7/7 [==============================] - 0s 15ms/step - loss: 1552.9727 -
val_loss: 1508.6826
Epoch 2/400
7/7 [==============================] - 0s 3ms/step - loss: 1546.8019 - val_loss:
1501.8268
Epoch 3/400
7/7 [==============================] - 0s 3ms/step - loss: 1539.6799 - val_loss:
1493.7604
Epoch 4/400
7/7 [==============================] - 0s 3ms/step - loss: 1531.0690 - val_loss:
1484.2760
Epoch 5/400
7/7 [==============================] - 0s 2ms/step - loss: 1521.1899 - val_loss:
1472.9838
Epoch 6/400
7/7 [==============================] - 0s 3ms/step - loss: 1509.3269 - val_loss:
1459.6383
Epoch 7/400
7/7 [==============================] - 0s 3ms/step - loss: 1495.1875 - val_loss:
1443.7256
```

```
Epoch 8/400
7/7 [==============================] - 0s 2ms/step - loss: 1478.3779 - val_loss:
1424.5239
Epoch 9/400
7/7 [==============================] - 0s 3ms/step - loss: 1457.9557 - val_loss:
1401.2220
Epoch 10/400
7/7 [==============================] - 0s 3ms/step - loss: 1433.4542 - val_loss:
1372.9393
Epoch 11/400
7/7 [==============================] - 0s 3ms/step - loss: 1403.0205 - val_loss:
1338.7654
Epoch 12/400
7/7 [==============================] - 0s 3ms/step - loss: 1366.2415 - val_loss:
1296.9757
Epoch 13/400
7/7 [==============================] - 0s 3ms/step - loss: 1321.2113 - val_loss:
1246.1107
Epoch 14/400
7/7 [==============================] - 0s 3ms/step - loss: 1267.1293 - val_loss:
1185.3334
Epoch 15/400
7/7 [==============================] - 0s 3ms/step - loss: 1202.4274 - val_loss:
1113.8789
Epoch 16/400
7/7 [==============================] - 0s 4ms/step - loss: 1126.9540 - val_loss:
1031.0339
Epoch 17/400
7/7 [==============================] - 0s 3ms/step - loss: 1040.9283 - val_loss:
937.4698
Epoch 18/400
7/7 [==============================] - 0s 3ms/step - loss: 942.9401 - val_loss:
835.0931
Epoch 19/400
7/7 [==============================] - 0s 3ms/step - loss: 836.8151 - val_loss:
725.8336
Epoch 20/400
7/7 [==============================] - 0s 3ms/step - loss: 726.3052 - val_loss:
612.7827
Epoch 21/400
7/7 [==============================] - 0s 3ms/step - loss: 614.0106 - val_loss:
503.3185
Epoch 22/400
7/7 [==============================] - 0s 3ms/step - loss: 508.7143 - val_loss:
403.9704
Epoch 23/400
7/7 [==============================] - 0s 3ms/step - loss: 412.0186 - val_loss:
322.6028
```

```
Epoch 24/400
7/7 [==============================] - 0s 3ms/step - loss: 339.5339 - val_loss:
262.1744
Epoch 25/400
7/7 [==============================] - 0s 3ms/step - loss: 287.3574 - val_loss:
226.4852
Epoch 26/400
7/7 [==============================] - 0s 3ms/step - loss: 257.6198 - val_loss:
210.8604
Epoch 27/400
7/7 [==============================] - 0s 3ms/step - loss: 245.8596 - val_loss:
206.9225
Epoch 28/400
7/7 [==============================] - 0s 3ms/step - loss: 241.9883 - val_loss:
206.7929
Epoch 29/400
7/7 [==============================] - 0s 3ms/step - loss: 241.2735 - val_loss:
206.4270
Epoch 30/400
7/7 [==============================] - 0s 3ms/step - loss: 240.0460 - val_loss:
205.2440
Epoch 31/400
7/7 [==============================] - 0s 3ms/step - loss: 237.9680 - val_loss:
203.5482
Epoch 32/400
7/7 [==============================] - 0s 3ms/step - loss: 235.9623 - val_loss:
201.9958
Epoch 33/400
7/7 [==============================] - 0s 3ms/step - loss: 234.2422 - val_loss:
200.7279
Epoch 34/400
7/7 [==============================] - 0s 3ms/step - loss: 232.5768 - val_loss:
199.5953
Epoch 35/400
7/7 [==============================] - 0s 3ms/step - loss: 230.9335 - val_loss:
198.4823
Epoch 36/400
7/7 [==============================] - 0s 3ms/step - loss: 229.1598 - val_loss:
197.3176
Epoch 37/400
7/7 [==============================] - 0s 3ms/step - loss: 227.3771 - val_loss:
196.0406
Epoch 38/400
7/7 [==============================] - 0s 3ms/step - loss: 225.5170 - val_loss:
194.6746
Epoch 39/400
7/7 [==============================] - 0s 3ms/step - loss: 223.4402 - val_loss:
193.1156
```

```
Epoch 40/400
7/7 [==============================] - 0s 3ms/step - loss: 221.2119 - val_loss:
191.6171
Epoch 41/400
7/7 [==============================] - 0s 3ms/step - loss: 218.7655 - val_loss:
190.0426
Epoch 42/400
7/7 [==============================] - 0s 3ms/step - loss: 216.1941 - val_loss:
188.3955
Epoch 43/400
7/7 [==============================] - 0s 3ms/step - loss: 213.4908 - val_loss:
186.6427
Epoch 44/400
7/7 [==============================] - 0s 3ms/step - loss: 210.6440 - val_loss:
184.7481
Epoch 45/400
7/7 [==============================] - 0s 3ms/step - loss: 207.5604 - val_loss:
182.7501
Epoch 46/400
7/7 [==============================] - 0s 3ms/step - loss: 204.4417 - val_loss:
180.7329
Epoch 47/400
7/7 [==============================] - 0s 3ms/step - loss: 201.1663 - val_loss:
178.7834
Epoch 48/400
7/7 [==============================] - 0s 3ms/step - loss: 198.1812 - val_loss:
176.7494
Epoch 49/400
7/7 [==============================] - 0s 3ms/step - loss: 195.0266 - val_loss:
174.7260
Epoch 50/400
7/7 [==============================] - 0s 3ms/step - loss: 191.9839 - val_loss:
172.7047
Epoch 51/400
7/7 [==============================] - 0s 3ms/step - loss: 188.9179 - val_loss:
170.5597
Epoch 52/400
7/7 [==============================] - 0s 3ms/step - loss: 185.9697 - val_loss:
168.4945
Epoch 53/400
7/7 [==============================] - 0s 3ms/step - loss: 182.8780 - val_loss:
166.5248
Epoch 54/400
7/7 [==============================] - 0s 3ms/step - loss: 180.1161 - val_loss:
164.6324
Epoch 55/400
7/7 [==============================] - 0s 3ms/step - loss: 177.4372 - val_loss:
162.7273
```

```
Epoch 56/400
7/7 [==============================] - 0s 3ms/step - loss: 174.7765 - val_loss:
160.8628
Epoch 57/400
7/7 [==============================] - 0s 3ms/step - loss: 172.1158 - val_loss:
159.0369
Epoch 58/400
7/7 [==============================] - 0s 2ms/step - loss: 169.7811 - val_loss:
157.2498
Epoch 59/400
7/7 [==============================] - 0s 2ms/step - loss: 167.2193 - val_loss:
155.5041
Epoch 60/400
7/7 [==============================] - 0s 2ms/step - loss: 164.8616 - val_loss:
153.7421
Epoch 61/400
7/7 [==============================] - 0s 3ms/step - loss: 162.3934 - val_loss:
152.0627
Epoch 62/400
7/7 [==============================] - 0s 2ms/step - loss: 160.2415 - val_loss:
150.3155
Epoch 63/400
7/7 [==============================] - 0s 2ms/step - loss: 157.9952 - val_loss:
148.6808
Epoch 64/400
7/7 [==============================] - 0s 2ms/step - loss: 155.9003 - val_loss:
147.0856
Epoch 65/400
7/7 [==============================] - 0s 2ms/step - loss: 153.8113 - val_loss:
145.4756
Epoch 66/400
7/7 [==============================] - 0s 2ms/step - loss: 151.8674 - val_loss:
143.9728
Epoch 67/400
7/7 [==============================] - 0s 2ms/step - loss: 150.1419 - val_loss:
142.4589
Epoch 68/400
7/7 [==============================] - 0s 2ms/step - loss: 148.2233 - val_loss:
140.8352
Epoch 69/400
7/7 [==============================] - 0s 2ms/step - loss: 146.6095 - val_loss:
139.3645
Epoch 70/400
7/7 [==============================] - 0s 2ms/step - loss: 144.9659 - val_loss:
137.9483
Epoch 71/400
7/7 [==============================] - 0s 2ms/step - loss: 143.3807 - val_loss:
136.5761
```

```
Epoch 72/400
7/7 [==============================] - 0s 3ms/step - loss: 141.9670 - val_loss:
135.2605
Epoch 73/400
7/7 [==============================] - 0s 3ms/step - loss: 140.5068 - val_loss:
133.8310
Epoch 74/400
7/7 [==============================] - 0s 3ms/step - loss: 139.2468 - val_loss:
132.4466
Epoch 75/400
7/7 [==============================] - 0s 2ms/step - loss: 137.9593 - val_loss:
131.0476
Epoch 76/400
7/7 [==============================] - 0s 2ms/step - loss: 136.6713 - val_loss:
129.8538
Epoch 77/400
7/7 [==============================] - 0s 3ms/step - loss: 135.5175 - val_loss:
128.7971
Epoch 78/400
7/7 [==============================] - 0s 3ms/step - loss: 134.5271 - val_loss:
127.6248
Epoch 79/400
7/7 [==============================] - 0s 2ms/step - loss: 133.4108 - val_loss:
126.4846
Epoch 80/400
7/7 [==============================] - 0s 2ms/step - loss: 132.4910 - val_loss:
125.4859
Epoch 81/400
7/7 [==============================] - 0s 2ms/step - loss: 131.5301 - val_loss:
124.4943
Epoch 82/400
7/7 [==============================] - 0s 2ms/step - loss: 130.7301 - val_loss:
123.4807
Epoch 83/400
7/7 [==============================] - 0s 2ms/step - loss: 130.0006 - val_loss:
122.5207
Epoch 84/400
7/7 [==============================] - 0s 2ms/step - loss: 129.2819 - val_loss:
121.5736
Epoch 85/400
7/7 [==============================] - 0s 2ms/step - loss: 128.4265 - val_loss:
120.5496
Epoch 86/400
7/7 [==============================] - 0s 2ms/step - loss: 127.7091 - val_loss:
119.7033
Epoch 87/400
7/7 [==============================] - 0s 2ms/step - loss: 127.1345 - val_loss:
118.9468
```

```
Epoch 88/400
7/7 [==============================] - 0s 2ms/step - loss: 126.4645 - val_loss:
118.1959
Epoch 89/400
7/7 [==============================] - 0s 2ms/step - loss: 125.9712 - val_loss:
117.3846
Epoch 90/400
7/7 [==============================] - 0s 2ms/step - loss: 125.3807 - val_loss:
116.7002
Epoch 91/400
7/7 [==============================] - 0s 2ms/step - loss: 124.9536 - val_loss:
115.9953
Epoch 92/400
7/7 [==============================] - 0s 2ms/step - loss: 124.5209 - val_loss:
115.3246
Epoch 93/400
7/7 [==============================] - 0s 2ms/step - loss: 124.0459 - val_loss:
114.6734
Epoch 94/400
7/7 [==============================] - 0s 2ms/step - loss: 123.6864 - val_loss:
114.1880
Epoch 95/400
7/7 [==============================] - 0s 2ms/step - loss: 123.3588 - val_loss:
113.6182
Epoch 96/400
7/7 [==============================] - 0s 2ms/step - loss: 122.8711 - val_loss:
113.0719
Epoch 97/400
7/7 [==============================] - 0s 2ms/step - loss: 122.5596 - val_loss:
112.5926
Epoch 98/400
7/7 [==============================] - 0s 2ms/step - loss: 122.2839 - val_loss:
112.0374
Epoch 99/400
7/7 [==============================] - 0s 2ms/step - loss: 122.0528 - val_loss:
111.4540
Epoch 100/400
7/7 [==============================] - 0s 2ms/step - loss: 121.6302 - val_loss:
110.8500
Epoch 101/400
7/7 [==============================] - 0s 2ms/step - loss: 121.4759 - val_loss:
110.2828
Epoch 102/400
7/7 [==============================] - 0s 2ms/step - loss: 121.0904 - val_loss:
109.6675
Epoch 103/400
7/7 [==============================] - 0s 2ms/step - loss: 121.0049 - val_loss:
109.4194
```

```
Epoch 104/400
7/7 [==============================] - 0s 2ms/step - loss: 120.6712 - val_loss:
108.9294
Epoch 105/400
7/7 [==============================] - 0s 2ms/step - loss: 120.4067 - val_loss:
108.4607
Epoch 106/400
7/7 [==============================] - 0s 2ms/step - loss: 120.1913 - val_loss:
108.2157
Epoch 107/400
7/7 [==============================] - 0s 2ms/step - loss: 120.0401 - val_loss:
107.7845
Epoch 108/400
7/7 [==============================] - 0s 2ms/step - loss: 119.8158 - val_loss:
107.5061
Epoch 109/400
7/7 [==============================] - 0s 2ms/step - loss: 120.0443 - val_loss:
107.5294
Epoch 110/400
7/7 [==============================] - 0s 2ms/step - loss: 119.6358 - val_loss:
106.9276
Epoch 111/400
7/7 [==============================] - 0s 2ms/step - loss: 119.1909 - val_loss:
106.6234
Epoch 112/400
7/7 [==============================] - 0s 2ms/step - loss: 119.2699 - val_loss:
106.4045
Epoch 113/400
7/7 [==============================] - 0s 2ms/step - loss: 119.0364 - val_loss:
106.0583
Epoch 114/400
7/7 [==============================] - 0s 2ms/step - loss: 118.8227 - val_loss:
105.8091
Epoch 115/400
7/7 [==============================] - 0s 2ms/step - loss: 118.6470 - val_loss:
105.7206
Epoch 116/400
7/7 [==============================] - 0s 2ms/step - loss: 118.5569 - val_loss:
105.4559
Epoch 117/400
7/7 [==============================] - 0s 2ms/step - loss: 118.3293 - val_loss:
105.1202
Epoch 118/400
7/7 [==============================] - 0s 2ms/step - loss: 118.3882 - val_loss:
105.0538
Epoch 119/400
7/7 [==============================] - 0s 2ms/step - loss: 118.1786 - val_loss:
104.7872
```

```
Epoch 120/400
7/7 [==============================] - 0s 2ms/step - loss: 117.9424 - val_loss:
104.4889
Epoch 121/400
7/7 [==============================] - 0s 3ms/step - loss: 117.8176 - val_loss:
104.3915
Epoch 122/400
7/7 [==============================] - 0s 2ms/step - loss: 117.7092 - val_loss:
104.2911
Epoch 123/400
7/7 [==============================] - 0s 3ms/step - loss: 117.6229 - val_loss:
104.1105
Epoch 124/400
7/7 [==============================] - 0s 3ms/step - loss: 117.4324 - val_loss:
103.8971
Epoch 125/400
7/7 [==============================] - 0s 2ms/step - loss: 117.2659 - val_loss:
103.6479
Epoch 126/400
7/7 [==============================] - 0s 2ms/step - loss: 117.2083 - val_loss:
103.5283
Epoch 127/400
7/7 [==============================] - 0s 2ms/step - loss: 117.0613 - val_loss:
103.2489
Epoch 128/400
7/7 [==============================] - 0s 2ms/step - loss: 116.9811 - val_loss:
103.2201
Epoch 129/400
7/7 [==============================] - 0s 2ms/step - loss: 116.8785 - val_loss:
103.0281
Epoch 130/400
7/7 [==============================] - 0s 2ms/step - loss: 116.7468 - val_loss:
102.7095
Epoch 131/400
7/7 [==============================] - 0s 2ms/step - loss: 116.5905 - val_loss:
102.4815
Epoch 132/400
7/7 [==============================] - 0s 2ms/step - loss: 116.4663 - val_loss:
102.3902
Epoch 133/400
7/7 [==============================] - 0s 2ms/step - loss: 116.4868 - val_loss:
102.3043
Epoch 134/400
7/7 [==============================] - 0s 2ms/step - loss: 116.3933 - val_loss:
102.0774
Epoch 135/400
7/7 [==============================] - 0s 2ms/step - loss: 116.2838 - val_loss:
102.0317
```

```
Epoch 136/400
7/7 [==============================] - 0s 2ms/step - loss: 116.1740 - val_loss:
101.7057
Epoch 137/400
7/7 [==============================] - 0s 2ms/step - loss: 115.9992 - val_loss:
101.5516
Epoch 138/400
7/7 [==============================] - 0s 2ms/step - loss: 115.8626 - val_loss:
101.4446
Epoch 139/400
7/7 [==============================] - 0s 2ms/step - loss: 115.7300 - val_loss:
101.3583
Epoch 140/400
7/7 [==============================] - 0s 2ms/step - loss: 115.7085 - val_loss:
101.2495
Epoch 141/400
7/7 [==============================] - 0s 2ms/step - loss: 115.7474 - val_loss:
101.0847
Epoch 142/400
7/7 [==============================] - 0s 2ms/step - loss: 115.4693 - val_loss:
100.8888
Epoch 143/400
7/7 [==============================] - 0s 2ms/step - loss: 115.5315 - val_loss:
100.9646
Epoch 144/400
7/7 [==============================] - 0s 2ms/step - loss: 115.3664 - val_loss:
100.5726
Epoch 145/400
7/7 [==============================] - 0s 2ms/step - loss: 115.1603 - val_loss:
100.4375
Epoch 146/400
7/7 [==============================] - 0s 2ms/step - loss: 115.0280 - val_loss:
100.2814
Epoch 147/400
7/7 [==============================] - 0s 2ms/step - loss: 114.9330 - val_loss:
100.1199
Epoch 148/400
7/7 [==============================] - 0s 2ms/step - loss: 114.8263 - val_loss:
99.9466
Epoch 149/400
7/7 [==============================] - 0s 2ms/step - loss: 114.9822 - val_loss:
99.8897
Epoch 150/400
7/7 [==============================] - 0s 2ms/step - loss: 114.5688 - val_loss:
99.5975
Epoch 151/400
7/7 [==============================] - 0s 2ms/step - loss: 114.8507 - val_loss:
99.6393
```

```
Epoch 152/400
7/7 [==============================] - 0s 2ms/step - loss: 114.5087 - val_loss:
99.4136
Epoch 153/400
7/7 [==============================] - 0s 2ms/step - loss: 114.4404 - val_loss:
99.4498
Epoch 154/400
7/7 [==============================] - 0s 2ms/step - loss: 114.4655 - val_loss:
99.4863
Epoch 155/400
7/7 [==============================] - 0s 2ms/step - loss: 114.3793 - val_loss:
99.2457
Epoch 156/400
7/7 [==============================] - 0s 2ms/step - loss: 114.2958 - val_loss:
99.2494
Epoch 157/400
7/7 [==============================] - 0s 2ms/step - loss: 114.1760 - val_loss:
99.3139
Epoch 158/400
7/7 [==============================] - 0s 2ms/step - loss: 113.9753 - val_loss:
99.0747
Epoch 159/400
7/7 [==============================] - 0s 2ms/step - loss: 114.0902 - val_loss:
98.8667
Epoch 160/400
7/7 [==============================] - 0s 2ms/step - loss: 114.0821 - val_loss:
98.7255
Epoch 161/400
7/7 [==============================] - 0s 2ms/step - loss: 113.9272 - val_loss:
98.5213
Epoch 162/400
7/7 [==============================] - 0s 2ms/step - loss: 113.6592 - val_loss:
98.2507
Epoch 163/400
7/7 [==============================] - 0s 2ms/step - loss: 113.8323 - val_loss:
98.2880
Epoch 164/400
7/7 [==============================] - 0s 2ms/step - loss: 113.5700 - val_loss:
98.1634
Epoch 165/400
7/7 [==============================] - 0s 2ms/step - loss: 113.6367 - val_loss:
98.1876
Epoch 166/400
7/7 [==============================] - 0s 2ms/step - loss: 113.3866 - val_loss:
98.4476
Epoch 167/400
7/7 [==============================] - 0s 2ms/step - loss: 113.4359 - val_loss:
98.2130
```

```
Epoch 168/400
7/7 [==============================] - 0s 2ms/step - loss: 113.2113 - val_loss:
98.1459
Epoch 169/400
7/7 [==============================] - 0s 2ms/step - loss: 113.4303 - val_loss:
97.9401
Epoch 170/400
7/7 [==============================] - 0s 2ms/step - loss: 112.9913 - val_loss:
97.8144
Epoch 171/400
7/7 [==============================] - 0s 2ms/step - loss: 112.9945 - val_loss:
97.7775
Epoch 172/400
7/7 [==============================] - 0s 2ms/step - loss: 112.9941 - val_loss:
97.5302
Epoch 173/400
7/7 [==============================] - 0s 2ms/step - loss: 112.9796 - val_loss:
97.4162
Epoch 174/400
7/7 [==============================] - 0s 2ms/step - loss: 112.7211 - val_loss:
97.3550
Epoch 175/400
7/7 [==============================] - 0s 2ms/step - loss: 112.7089 - val_loss:
97.2983
Epoch 176/400
7/7 [==============================] - 0s 2ms/step - loss: 112.8753 - val_loss:
97.1980
Epoch 177/400
7/7 [==============================] - 0s 2ms/step - loss: 112.6665 - val_loss:
97.0607
Epoch 178/400
7/7 [==============================] - 0s 2ms/step - loss: 112.5384 - val_loss:
96.9607
Epoch 179/400
7/7 [==============================] - 0s 2ms/step - loss: 112.4948 - val_loss:
96.7968
Epoch 180/400
7/7 [==============================] - 0s 2ms/step - loss: 112.3962 - val_loss:
96.7701
Epoch 181/400
7/7 [==============================] - 0s 2ms/step - loss: 112.3317 - val_loss:
96.8539
Epoch 182/400
7/7 [==============================] - 0s 2ms/step - loss: 112.2026 - val_loss:
96.8780
Epoch 183/400
7/7 [==============================] - 0s 2ms/step - loss: 112.1889 - val_loss:
96.7547
```

```
Epoch 184/400
7/7 [==============================] - 0s 2ms/step - loss: 112.0092 - val_loss:
96.7415
Epoch 185/400
7/7 [==============================] - 0s 2ms/step - loss: 112.0499 - val_loss:
96.6603
Epoch 186/400
7/7 [==============================] - 0s 2ms/step - loss: 112.0162 - val_loss:
96.6543
Epoch 187/400
7/7 [==============================] - 0s 2ms/step - loss: 111.9374 - val_loss:
96.5197
Epoch 188/400
7/7 [==============================] - 0s 2ms/step - loss: 111.9559 - val_loss:
96.4028
Epoch 189/400
7/7 [==============================] - 0s 2ms/step - loss: 111.7911 - val_loss:
96.2907
Epoch 190/400
7/7 [==============================] - 0s 2ms/step - loss: 111.6954 - val_loss:
96.3617
Epoch 191/400
7/7 [==============================] - 0s 2ms/step - loss: 111.6601 - val_loss:
96.3378
Epoch 192/400
7/7 [==============================] - 0s 2ms/step - loss: 111.8684 - val_loss:
96.2949
Epoch 193/400
7/7 [==============================] - 0s 2ms/step - loss: 111.4508 - val_loss:
96.2246
Epoch 194/400
7/7 [==============================] - 0s 2ms/step - loss: 111.5027 - val_loss:
96.2053
Epoch 195/400
7/7 [==============================] - 0s 2ms/step - loss: 111.4261 - val_loss:
95.9865
Epoch 196/400
7/7 [==============================] - 0s 2ms/step - loss: 111.3753 - val_loss:
95.8391
Epoch 197/400
7/7 [==============================] - 0s 2ms/step - loss: 111.3863 - val_loss:
95.6005
Epoch 198/400
7/7 [==============================] - 0s 2ms/step - loss: 111.4314 - val_loss:
95.5975
Epoch 199/400
7/7 [==============================] - 0s 2ms/step - loss: 111.1537 - val_loss:
95.6367
```

```
Epoch 200/400
7/7 [==============================] - 0s 2ms/step - loss: 111.1341 - val_loss:
95.4210
Epoch 201/400
7/7 [==============================] - 0s 2ms/step - loss: 111.0793 - val_loss:
95.3763
Epoch 202/400
7/7 [==============================] - 0s 2ms/step - loss: 111.0043 - val_loss:
95.1209
Epoch 203/400
7/7 [==============================] - 0s 2ms/step - loss: 110.8929 - val_loss:
95.2011
Epoch 204/400
7/7 [==============================] - 0s 2ms/step - loss: 111.0620 - val_loss:
95.1269
Epoch 205/400
7/7 [==============================] - 0s 2ms/step - loss: 111.0477 - val_loss:
95.2117
Epoch 206/400
7/7 [==============================] - 0s 2ms/step - loss: 110.8770 - val_loss:
94.9300
Epoch 207/400
7/7 [==============================] - 0s 2ms/step - loss: 110.6467 - val_loss:
94.9835
Epoch 208/400
7/7 [==============================] - 0s 2ms/step - loss: 110.8749 - val_loss:
95.0819
Epoch 209/400
7/7 [==============================] - 0s 2ms/step - loss: 110.8082 - val_loss:
95.1838
Epoch 210/400
7/7 [==============================] - 0s 2ms/step - loss: 110.5702 - val_loss:
95.0918
Epoch 211/400
7/7 [==============================] - 0s 2ms/step - loss: 110.5238 - val_loss:
95.0891
Epoch 212/400
7/7 [==============================] - 0s 2ms/step - loss: 110.4726 - val_loss:
95.0525
Epoch 213/400
7/7 [==============================] - 0s 2ms/step - loss: 110.4329 - val_loss:
94.9858
Epoch 214/400
7/7 [==============================] - 0s 2ms/step - loss: 110.3527 - val_loss:
94.8959
Epoch 215/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2845 - val_loss:
94.8457
```

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Epoch 216/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2300 - val_loss:
94.7538
Epoch 217/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2444 - val_loss:
94.5517
Epoch 218/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2809 - val_loss:
94.4669
Epoch 219/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2460 - val_loss:
94.1132
Epoch 220/400
7/7 [==============================] - 0s 2ms/step - loss: 110.0957 - val_loss:
94.0750
Epoch 221/400
7/7 [==============================] - 0s 2ms/step - loss: 110.2290 - val_loss:
93.9292
Epoch 222/400
7/7 [==============================] - 0s 2ms/step - loss: 110.1527 - val_loss:
93.9226
Epoch 223/400
7/7 [==============================] - 0s 2ms/step - loss: 109.7665 - val_loss:
93.9984
Epoch 224/400
7/7 [==============================] - 0s 2ms/step - loss: 110.0294 - val_loss:
93.8837
Epoch 225/400
7/7 [==============================] - 0s 2ms/step - loss: 109.9474 - val_loss:
93.8100
Epoch 226/400
7/7 [==============================] - 0s 2ms/step - loss: 109.7244 - val_loss:
93.9296
Epoch 227/400
7/7 [==============================] - 0s 2ms/step - loss: 109.9418 - val_loss:
94.0417
Epoch 228/400
7/7 [==============================] - 0s 2ms/step - loss: 109.6150 - val_loss:
94.0717
Epoch 229/400
7/7 [==============================] - 0s 2ms/step - loss: 109.6181 - val_loss:
94.3192
Epoch 230/400
7/7 [==============================] - 0s 2ms/step - loss: 109.6244 - val_loss:
94.1431
Epoch 231/400
7/7 [==============================] - 0s 2ms/step - loss: 109.6919 - val_loss:
94.0879
```

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Epoch 232/400
7/7 [==============================] - 0s 2ms/step - loss: 109.4418 - val_loss:
94.1189
Epoch 233/400
7/7 [==============================] - 0s 2ms/step - loss: 109.4400 - val_loss:
93.9283
Epoch 234/400
7/7 [==============================] - 0s 2ms/step - loss: 109.4592 - val_loss:
93.8547
Epoch 235/400
7/7 [==============================] - 0s 2ms/step - loss: 109.3862 - val_loss:
93.7979
Epoch 236/400
7/7 [==============================] - 0s 2ms/step - loss: 109.3863 - val_loss:
93.4986
Epoch 237/400
7/7 [==============================] - 0s 2ms/step - loss: 109.2550 - val_loss:
93.4712
Epoch 238/400
7/7 [==============================] - 0s 2ms/step - loss: 109.1952 - val_loss:
93.3166
Epoch 239/400
7/7 [==============================] - 0s 2ms/step - loss: 109.2004 - val_loss:
93.4064
Epoch 240/400
7/7 [==============================] - 0s 2ms/step - loss: 109.3546 - val_loss:
93.2833
Epoch 241/400
7/7 [==============================] - 0s 2ms/step - loss: 109.0719 - val_loss:
93.2078
Epoch 242/400
7/7 [==============================] - 0s 2ms/step - loss: 109.0969 - val_loss:
93.1459
Epoch 243/400
7/7 [==============================] - 0s 2ms/step - loss: 108.9591 - val_loss:
92.9707
Epoch 244/400
7/7 [==============================] - 0s 2ms/step - loss: 108.9380 - val_loss:
92.9697
Epoch 245/400
7/7 [==============================] - 0s 2ms/step - loss: 108.9938 - val_loss:
93.0496
Epoch 246/400
7/7 [==============================] - 0s 2ms/step - loss: 108.9562 - val_loss:
93.0352
Epoch 247/400
7/7 [==============================] - 0s 2ms/step - loss: 108.8487 - val_loss:
92.9395
```

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Epoch 248/400
7/7 [==============================] - 0s 2ms/step - loss: 108.7742 - val_loss:
92.9257
Epoch 249/400
7/7 [==============================] - 0s 2ms/step - loss: 108.7643 - val_loss:
92.9616
Epoch 250/400
7/7 [==============================] - 0s 2ms/step - loss: 108.6855 - val_loss:
92.9895
Epoch 251/400
7/7 [==============================] - 0s 2ms/step - loss: 108.8839 - val_loss:
92.9627
Epoch 252/400
7/7 [==============================] - 0s 2ms/step - loss: 108.5200 - val_loss:
92.7725
Epoch 253/400
7/7 [==============================] - 0s 2ms/step - loss: 108.6306 - val_loss:
92.7595
Epoch 254/400
7/7 [==============================] - 0s 2ms/step - loss: 108.4763 - val_loss:
92.5952
Epoch 255/400
7/7 [==============================] - 0s 2ms/step - loss: 108.4597 - val_loss:
92.6251
Epoch 256/400
7/7 [==============================] - 0s 2ms/step - loss: 108.4337 - val_loss:
92.4450
Epoch 257/400
7/7 [==============================] - 0s 2ms/step - loss: 108.5468 - val_loss:
92.5104
Epoch 258/400
7/7 [==============================] - 0s 2ms/step - loss: 108.3783 - val_loss:
92.4864
Epoch 259/400
7/7 [==============================] - 0s 2ms/step - loss: 108.3201 - val_loss:
92.4304
Epoch 260/400
7/7 [==============================] - 0s 2ms/step - loss: 108.2534 - val_loss:
92.2525
Epoch 261/400
7/7 [==============================] - 0s 2ms/step - loss: 108.2225 - val_loss:
92.1486
Epoch 262/400
7/7 [==============================] - 0s 2ms/step - loss: 108.2275 - val_loss:
92.1146
Epoch 263/400
7/7 [==============================] - 0s 2ms/step - loss: 108.2157 - val_loss:
92.0382
```

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Epoch 264/400
7/7 [==============================] - 0s 2ms/step - loss: 108.2683 - val_loss:
92.0382
Epoch 265/400
7/7 [==============================] - 0s 2ms/step - loss: 108.0705 - val_loss:
91.8925
Epoch 266/400
7/7 [==============================] - 0s 2ms/step - loss: 108.0793 - val_loss:
91.8409
Epoch 267/400
7/7 [==============================] - 0s 2ms/step - loss: 108.0595 - val_loss:
91.8852
Epoch 268/400
7/7 [==============================] - 0s 2ms/step - loss: 107.9479 - val_loss:
91.9477
Epoch 269/400
7/7 [==============================] - 0s 2ms/step - loss: 107.9050 - val_loss:
91.9490
Epoch 270/400
7/7 [==============================] - 0s 2ms/step - loss: 107.9049 - val_loss:
91.9526
Epoch 271/400
7/7 [==============================] - 0s 2ms/step - loss: 107.8872 - val_loss:
91.9918
Epoch 272/400
7/7 [==============================] - 0s 2ms/step - loss: 107.8142 - val_loss:
91.9117
Epoch 273/400
7/7 [==============================] - 0s 2ms/step - loss: 107.8839 - val_loss:
92.0425
Epoch 274/400
7/7 [==============================] - 0s 2ms/step - loss: 107.6276 - val_loss:
91.7895
Epoch 275/400
7/7 [==============================] - 0s 2ms/step - loss: 108.1815 - val_loss:
91.7594
Epoch 276/400
7/7 [==============================] - 0s 2ms/step - loss: 107.7777 - val_loss:
91.9985
Epoch 277/400
7/7 [==============================] - 0s 2ms/step - loss: 108.0248 - val_loss:
91.5295
Epoch 278/400
7/7 [==============================] - 0s 2ms/step - loss: 107.5551 - val_loss:
91.4496
Epoch 279/400
7/7 [==============================] - 0s 2ms/step - loss: 107.5445 - val_loss:
91.4282
```

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Epoch 280/400
7/7 [==============================] - 0s 2ms/step - loss: 107.5005 - val_loss:
91.2104
Epoch 281/400
7/7 [==============================] - 0s 2ms/step - loss: 107.4537 - val_loss:
91.0164
Epoch 282/400
7/7 [==============================] - 0s 2ms/step - loss: 107.5697 - val_loss:
91.0050
Epoch 283/400
7/7 [==============================] - 0s 2ms/step - loss: 107.3894 - val_loss:
90.9654
Epoch 284/400
7/7 [==============================] - 0s 2ms/step - loss: 107.3897 - val_loss:
91.0169
Epoch 285/400
7/7 [==============================] - 0s 2ms/step - loss: 107.4831 - val_loss:
90.9688
Epoch 286/400
7/7 [==============================] - 0s 2ms/step - loss: 107.2585 - val_loss:
91.2028
Epoch 287/400
7/7 [==============================] - 0s 2ms/step - loss: 107.3202 - val_loss:
90.8020
Epoch 288/400
7/7 [==============================] - 0s 3ms/step - loss: 107.1462 - val_loss:
90.9637
Epoch 289/400
7/7 [==============================] - 0s 3ms/step - loss: 107.2495 - val_loss:
90.9879
Epoch 290/400
7/7 [==============================] - 0s 3ms/step - loss: 107.1872 - val_loss:
90.9335
Epoch 291/400
7/7 [==============================] - 0s 5ms/step - loss: 107.2631 - val_loss:
90.7432
Epoch 292/400
7/7 [==============================] - 0s 4ms/step - loss: 106.9118 - val_loss:
90.7107
Epoch 293/400
7/7 [==============================] - 0s 4ms/step - loss: 107.2628 - val_loss:
90.7736
Epoch 294/400
7/7 [==============================] - 0s 3ms/step - loss: 106.8186 - val_loss:
90.6068
Epoch 295/400
7/7 [==============================] - 0s 3ms/step - loss: 107.3433 - val_loss:
90.7362
```

```
Epoch 296/400
7/7 [==============================] - 0s 3ms/step - loss: 106.9650 - val_loss:
90.6128
Epoch 297/400
7/7 [==============================] - 0s 3ms/step - loss: 107.0272 - val_loss:
90.6022
Epoch 298/400
7/7 [==============================] - 0s 3ms/step - loss: 107.0497 - val_loss:
90.5048
Epoch 299/400
7/7 [==============================] - 0s 3ms/step - loss: 106.7320 - val_loss:
90.5234
Epoch 300/400
7/7 [==============================] - 0s 3ms/step - loss: 106.7487 - val_loss:
90.5646
Epoch 301/400
7/7 [==============================] - 0s 2ms/step - loss: 106.8900 - val_loss:
90.4839
Epoch 302/400
7/7 [==============================] - 0s 2ms/step - loss: 106.5915 - val_loss:
90.4033
Epoch 303/400
7/7 [==============================] - 0s 2ms/step - loss: 106.6946 - val_loss:
90.1220
Epoch 304/400
7/7 [==============================] - 0s 2ms/step - loss: 106.5238 - val_loss:
89.9594
Epoch 305/400
7/7 [==============================] - 0s 2ms/step - loss: 106.5235 - val_loss:
89.9063
Epoch 306/400
7/7 [==============================] - 0s 2ms/step - loss: 107.0535 - val_loss:
90.2001
Epoch 307/400
7/7 [==============================] - 0s 2ms/step - loss: 106.9108 - val_loss:
90.3720
Epoch 308/400
7/7 [==============================] - 0s 2ms/step - loss: 106.6754 - val_loss:
90.2488
Epoch 309/400
7/7 [==============================] - 0s 2ms/step - loss: 106.3072 - val_loss:
90.1371
Epoch 310/400
7/7 [==============================] - 0s 2ms/step - loss: 106.3599 - val_loss:
89.9433
Epoch 311/400
7/7 [==============================] - 0s 2ms/step - loss: 106.1619 - val_loss:
89.9835
```

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Epoch 312/400
7/7 [==============================] - 0s 2ms/step - loss: 106.3104 - val_loss:
89.7816
Epoch 313/400
7/7 [==============================] - 0s 2ms/step - loss: 106.2566 - val_loss:
89.8127
Epoch 314/400
7/7 [==============================] - 0s 2ms/step - loss: 106.6480 - val_loss:
89.4398
Epoch 315/400
7/7 [==============================] - 0s 2ms/step - loss: 106.1748 - val_loss:
89.4602
Epoch 316/400
7/7 [==============================] - 0s 2ms/step - loss: 106.0544 - val_loss:
89.3163
Epoch 317/400
7/7 [==============================] - 0s 2ms/step - loss: 106.1250 - val_loss:
89.3851
Epoch 318/400
7/7 [==============================] - 0s 2ms/step - loss: 106.1774 - val_loss:
89.4258
Epoch 319/400
7/7 [==============================] - 0s 2ms/step - loss: 105.9564 - val_loss:
89.2462
Epoch 320/400
7/7 [==============================] - 0s 2ms/step - loss: 106.0643 - val_loss:
89.3276
Epoch 321/400
7/7 [==============================] - 0s 2ms/step - loss: 105.8002 - val_loss:
89.0243
Epoch 322/400
7/7 [==============================] - 0s 2ms/step - loss: 105.8372 - val_loss:
89.0964
Epoch 323/400
7/7 [==============================] - 0s 2ms/step - loss: 105.8320 - val_loss:
89.1280
Epoch 324/400
7/7 [==============================] - 0s 2ms/step - loss: 105.6375 - val_loss:
89.0750
Epoch 325/400
7/7 [==============================] - 0s 2ms/step - loss: 105.6565 - val_loss:
89.1161
Epoch 326/400
7/7 [==============================] - 0s 2ms/step - loss: 105.6311 - val_loss:
89.2524
Epoch 327/400
7/7 [==============================] - 0s 2ms/step - loss: 105.4883 - val_loss:
89.0969
```

```
Epoch 328/400
7/7 [==============================] - 0s 2ms/step - loss: 105.6745 - val_loss:
89.0379
Epoch 329/400
7/7 [==============================] - 0s 2ms/step - loss: 105.4730 - val_loss:
89.0415
Epoch 330/400
7/7 [==============================] - 0s 2ms/step - loss: 105.3364 - val_loss:
89.0840
Epoch 331/400
7/7 [==============================] - 0s 2ms/step - loss: 105.3858 - val_loss:
89.0393
Epoch 332/400
7/7 [==============================] - 0s 2ms/step - loss: 105.3416 - val_loss:
89.0318
Epoch 333/400
7/7 [==============================] - 0s 2ms/step - loss: 105.2558 - val_loss:
89.0396
Epoch 334/400
7/7 [==============================] - 0s 2ms/step - loss: 105.2642 - val_loss:
88.9609
Epoch 335/400
7/7 [==============================] - 0s 2ms/step - loss: 105.3856 - val_loss:
88.9875
Epoch 336/400
7/7 [==============================] - 0s 2ms/step - loss: 105.0856 - val_loss:
88.8372
Epoch 337/400
7/7 [==============================] - 0s 2ms/step - loss: 105.5450 - val_loss:
88.9570
Epoch 338/400
7/7 [==============================] - 0s 2ms/step - loss: 104.9995 - val_loss:
88.6934
Epoch 339/400
7/7 [==============================] - 0s 2ms/step - loss: 105.6272 - val_loss:
89.0202
Epoch 340/400
7/7 [==============================] - 0s 2ms/step - loss: 104.9551 - val_loss:
88.5338
Epoch 341/400
7/7 [==============================] - 0s 2ms/step - loss: 105.3322 - val_loss:
88.5323
Epoch 342/400
7/7 [==============================] - 0s 2ms/step - loss: 105.0755 - val_loss:
88.8141
Epoch 343/400
7/7 [==============================] - 0s 2ms/step - loss: 104.9156 - val_loss:
88.6516
```

```
Epoch 344/400
7/7 [==============================] - 0s 2ms/step - loss: 104.7249 - val_loss:
88.5214
Epoch 345/400
7/7 [==============================] - 0s 2ms/step - loss: 104.7497 - val_loss:
88.3561
Epoch 346/400
7/7 [==============================] - 0s 2ms/step - loss: 104.6624 - val_loss:
88.3316
Epoch 347/400
7/7 [==============================] - 0s 2ms/step - loss: 104.7450 - val_loss:
88.3274
Epoch 348/400
7/7 [==============================] - 0s 2ms/step - loss: 104.7111 - val_loss:
88.1759
Epoch 349/400
7/7 [==============================] - 0s 2ms/step - loss: 104.5184 - val_loss:
88.1366
Epoch 350/400
7/7 [==============================] - 0s 2ms/step - loss: 104.4378 - val_loss:
87.9984
Epoch 351/400
7/7 [==============================] - 0s 2ms/step - loss: 104.7001 - val_loss:
88.0809
Epoch 352/400
7/7 [==============================] - 0s 3ms/step - loss: 104.2863 - val_loss:
88.1317
Epoch 353/400
7/7 [==============================] - 0s 3ms/step - loss: 104.2594 - val_loss:
87.8934
Epoch 354/400
7/7 [==============================] - 0s 2ms/step - loss: 104.2755 - val_loss:
87.8308
Epoch 355/400
7/7 [==============================] - 0s 2ms/step - loss: 104.3294 - val_loss:
87.5595
Epoch 356/400
7/7 [==============================] - 0s 2ms/step - loss: 104.4677 - val_loss:
87.4594
Epoch 357/400
7/7 [==============================] - 0s 2ms/step - loss: 104.3440 - val_loss:
87.6549
Epoch 358/400
7/7 [==============================] - 0s 2ms/step - loss: 104.0393 - val_loss:
87.5449
Epoch 359/400
7/7 [==============================] - 0s 2ms/step - loss: 103.9162 - val_loss:
87.4992
```

```
Epoch 360/400
7/7 [==============================] - 0s 2ms/step - loss: 103.7980 - val_loss:
87.4828
Epoch 361/400
7/7 [==============================] - 0s 2ms/step - loss: 103.9306 - val_loss:
87.5637
Epoch 362/400
7/7 [==============================] - 0s 2ms/step - loss: 103.8258 - val_loss:
87.5539
Epoch 363/400
7/7 [==============================] - 0s 2ms/step - loss: 103.7132 - val_loss:
87.3636
Epoch 364/400
7/7 [==============================] - 0s 2ms/step - loss: 103.5578 - val_loss:
87.2162
Epoch 365/400
7/7 [==============================] - 0s 2ms/step - loss: 103.5888 - val_loss:
87.0727
Epoch 366/400
7/7 [==============================] - 0s 2ms/step - loss: 103.4689 - val_loss:
87.0907
Epoch 367/400
7/7 [==============================] - 0s 2ms/step - loss: 103.5402 - val_loss:
86.9665
Epoch 368/400
7/7 [==============================] - 0s 2ms/step - loss: 103.3234 - val_loss:
87.1883
Epoch 369/400
7/7 [==============================] - 0s 2ms/step - loss: 103.4298 - val_loss:
86.9121
Epoch 370/400
7/7 [==============================] - 0s 2ms/step - loss: 103.2647 - val_loss:
87.0738
Epoch 371/400
7/7 [==============================] - 0s 2ms/step - loss: 103.1483 - val_loss:
86.9626
Epoch 372/400
7/7 [==============================] - 0s 2ms/step - loss: 103.1694 - val_loss:
86.8144
Epoch 373/400
7/7 [==============================] - 0s 2ms/step - loss: 103.0251 - val_loss:
86.7200
Epoch 374/400
7/7 [==============================] - 0s 2ms/step - loss: 103.0871 - val_loss:
86.6844
Epoch 375/400
7/7 [==============================] - 0s 2ms/step - loss: 102.8418 - val_loss:
86.4586
```

```
Epoch 376/400
7/7 [==============================] - 0s 2ms/step - loss: 102.9794 - val_loss:
86.4156
Epoch 377/400
7/7 [==============================] - 0s 2ms/step - loss: 102.7415 - val_loss:
86.3482
Epoch 378/400
7/7 [==============================] - 0s 2ms/step - loss: 102.7534 - val_loss:
86.4119
Epoch 379/400
7/7 [==============================] - 0s 2ms/step - loss: 102.7407 - val_loss:
86.3798
Epoch 380/400
7/7 [==============================] - 0s 2ms/step - loss: 102.5312 - val_loss:
86.3118
Epoch 381/400
7/7 [==============================] - 0s 2ms/step - loss: 102.5631 - val_loss:
86.5173
Epoch 382/400
7/7 [==============================] - 0s 2ms/step - loss: 102.5202 - val_loss:
86.5278
Epoch 383/400
7/7 [==============================] - 0s 2ms/step - loss: 102.4398 - val_loss:
86.5065
Epoch 384/400
7/7 [==============================] - 0s 2ms/step - loss: 102.4461 - val_loss:
86.5765
Epoch 385/400
7/7 [==============================] - 0s 2ms/step - loss: 102.1676 - val_loss:
86.5478
Epoch 386/400
7/7 [==============================] - 0s 2ms/step - loss: 102.1925 - val_loss:
86.2819
Epoch 387/400
7/7 [==============================] - 0s 2ms/step - loss: 102.1791 - val_loss:
86.4750
Epoch 388/400
7/7 [==============================] - 0s 2ms/step - loss: 102.1355 - val_loss:
86.4303
Epoch 389/400
7/7 [==============================] - 0s 2ms/step - loss: 101.9869 - val_loss:
86.0567
Epoch 390/400
7/7 [==============================] - 0s 2ms/step - loss: 101.9448 - val_loss:
85.9176
Epoch 391/400
7/7 [==============================] - 0s 2ms/step - loss: 101.9643 - val_loss:
85.8059
```

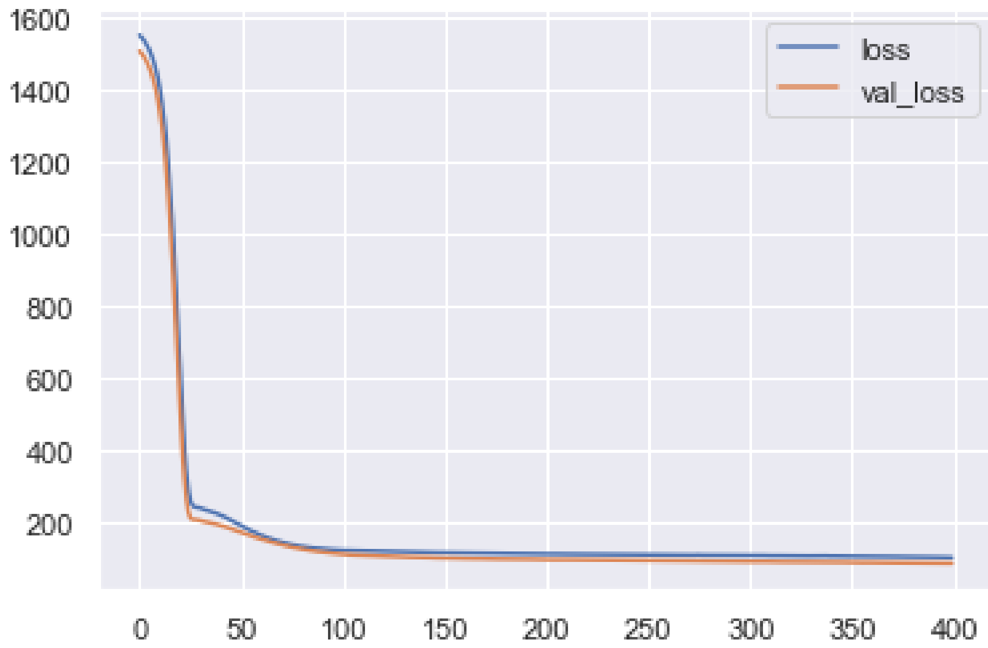
```
Epoch 392/400
7/7 [==============================] - 0s 2ms/step - loss: 101.8104 - val_loss:
85.8079
Epoch 393/400
7/7 [==============================] - 0s 2ms/step - loss: 101.5432 - val_loss:
85.6956
Epoch 394/400
7/7 [==============================] - 0s 2ms/step - loss: 101.9851 - val_loss:
85.4088
Epoch 395/400
7/7 [==============================] - 0s 2ms/step - loss: 101.5903 - val_loss:
85.8008
Epoch 396/400
7/7 [==============================] - 0s 2ms/step - loss: 101.6072 - val_loss:
85.7080
Epoch 397/400
7/7 [==============================] - 0s 2ms/step - loss: 101.4922 - val_loss:
85.5263
Epoch 398/400
7/7 [==============================] - 0s 2ms/step - loss: 101.1608 - val_loss:
85.3534
Epoch 399/400
7/7 [==============================] - 0s 2ms/step - loss: 101.2316 - val_loss:
85.2148
Epoch 400/400
7/7 [==============================] - 0s 2ms/step - loss: 100.9432 - val_loss:
85.2549
```

[21]:
```
<tensorflow.python.keras.callbacks.History at 0x7fe7422d1d60>
```

1.4.3 Visualize the Loss Function

[22]:
```
losses = pd.DataFrame(model.history.history)
losses.plot()
```

[22]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe742ba8b20>
```



Since the validation loss stays below the actual loss and continues to delcine with it, we observe that overfitting is minimal.

1.4.4 Test the Model

[23]:
```
predictions = model.predict(X_test)
```

1.4.5 Model Evaluation

[27]:
```
# Model Evaluation Metrics
MAE = mean_absolute_error(y_test,predictions)
RMSE = np.sqrt(mean_squared_error(y_test,predictions))
EVS = explained_variance_score(y_test,predictions)

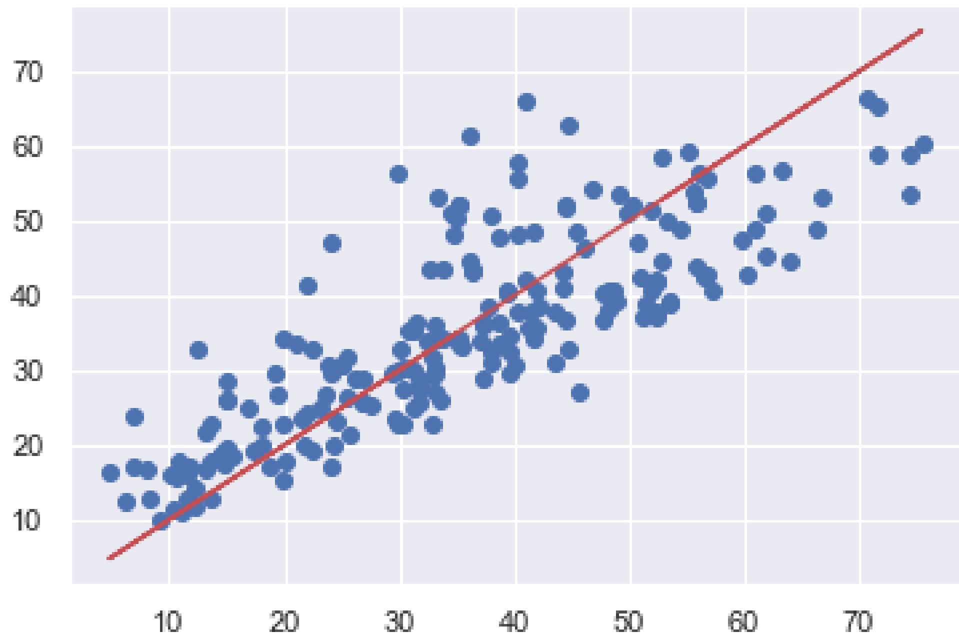
print('EVALUATION METRICS')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE}\nExplained Variance Score:\t\t{EVS}")
```

```
EVALUATION METRICS
-----------------------------
Mean Absolute Error (MAE):            7.23883411296363
Root Mean Squared Error (RMSE):       9.233359748913385
Explained Variance Score:             0.6691982422589368
```

[28]:
```
# Plot Model Predictions (Scatter)
plt.scatter(y_test,predictions)

# Plot Perfect predictions (Line)
plt.plot(y_test,y_test,'r')
```

[28]: [<matplotlib.lines.Line2D at 0x7fe742f6b070>]



There is clearly a wide spread of predicted values away from the perfect values. Let us experiment with adding more hidden nodes in the next section to try to increase the performance of our model.

1.5 Model 2 - ANN with 10 Hidden Layers

1.5.1 Construct the Artificial Neural Network

[34]:
```
model_2 = Sequential()

# Experiment with 10 hidden layers
model_2.add(Dense(8,activation='relu')) # All layers utilize rectified linear␣
↪units (relu)
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
```

```
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(8,activation='relu'))
model_2.add(Dense(4,activation='relu')) # Experiment with number of nodes
model_2.add(Dense(2,activation='relu'))
model_2.add(Dense(1))

model_2.compile(optimizer='adam',loss='mse') # Use the adam optimization␣
↪algorithm
```

1.5.2 Train the Model on the Test Data

[35]:
```
model_2.fit(x=X_train,y=y_train.values,
          validation_data=(X_test,y_test.values),
          batch_size=128,epochs=400)
```

```
Epoch 1/400
7/7 [==============================] - 0s 15ms/step - loss: 1569.2802 -
val_loss: 1527.6510
Epoch 2/400
7/7 [==============================] - 0s 3ms/step - loss: 1567.6498 - val_loss:
1525.9512
Epoch 3/400
7/7 [==============================] - 0s 3ms/step - loss: 1565.8867 - val_loss:
1524.0394
Epoch 4/400
7/7 [==============================] - 0s 3ms/step - loss: 1563.7501 - val_loss:
1521.6041
Epoch 5/400
7/7 [==============================] - 0s 3ms/step - loss: 1561.0574 - val_loss:
1518.4763
Epoch 6/400
7/7 [==============================] - 0s 3ms/step - loss: 1557.5063 - val_loss:
1514.2502
Epoch 7/400
7/7 [==============================] - 0s 3ms/step - loss: 1552.6052 - val_loss:
1508.2246
Epoch 8/400
7/7 [==============================] - 0s 3ms/step - loss: 1545.5275 - val_loss:
1499.2045
Epoch 9/400
7/7 [==============================] - 0s 3ms/step - loss: 1534.7487 - val_loss:
1485.1907
Epoch 10/400
7/7 [==============================] - 0s 3ms/step - loss: 1517.7587 - val_loss:
1462.8864
Epoch 11/400
7/7 [==============================] - 0s 4ms/step - loss: 1490.5731 - val_loss:
```

```
1426.7305
Epoch 12/400
7/7 [==============================] - 0s 3ms/step - loss: 1446.4495 - val_loss:
1368.1099
Epoch 13/400
7/7 [==============================] - 0s 4ms/step - loss: 1375.7881 - val_loss:
1273.9249
Epoch 14/400
7/7 [==============================] - 0s 4ms/step - loss: 1261.6282 - val_loss:
1126.3063
Epoch 15/400
7/7 [==============================] - 0s 3ms/step - loss: 1086.6063 - val_loss:
907.5222
Epoch 16/400
7/7 [==============================] - 0s 4ms/step - loss: 838.7682 - val_loss:
618.4327
Epoch 17/400
7/7 [==============================] - 0s 3ms/step - loss: 541.8533 - val_loss:
330.0607
Epoch 18/400
7/7 [==============================] - 0s 4ms/step - loss: 314.1353 - val_loss:
237.3927
Epoch 19/400
7/7 [==============================] - 0s 3ms/step - loss: 310.0399 - val_loss:
267.9193
Epoch 20/400
7/7 [==============================] - 0s 3ms/step - loss: 298.0985 - val_loss:
230.1266
Epoch 21/400
7/7 [==============================] - 0s 3ms/step - loss: 273.9677 - val_loss:
232.7351
Epoch 22/400
7/7 [==============================] - 0s 4ms/step - loss: 277.0691 - val_loss:
231.9311
Epoch 23/400
7/7 [==============================] - 0s 4ms/step - loss: 270.3176 - val_loss:
224.0883
Epoch 24/400
7/7 [==============================] - 0s 4ms/step - loss: 265.5859 - val_loss:
222.0743
Epoch 25/400
7/7 [==============================] - 0s 4ms/step - loss: 262.4738 - val_loss:
220.2853
Epoch 26/400
7/7 [==============================] - 0s 3ms/step - loss: 259.6396 - val_loss:
218.4978
Epoch 27/400
7/7 [==============================] - 0s 3ms/step - loss: 256.9294 - val_loss:
```

```
217.2043
Epoch 28/400
7/7 [==============================] - 0s 3ms/step - loss: 254.8800 - val_loss:
215.9870
Epoch 29/400
7/7 [==============================] - 0s 3ms/step - loss: 252.8027 - val_loss:
214.0839
Epoch 30/400
7/7 [==============================] - 0s 4ms/step - loss: 250.2803 - val_loss:
212.6586
Epoch 31/400
7/7 [==============================] - 0s 3ms/step - loss: 247.6571 - val_loss:
211.2211
Epoch 32/400
7/7 [==============================] - 0s 4ms/step - loss: 245.6166 - val_loss:
209.9449
Epoch 33/400
7/7 [==============================] - 0s 3ms/step - loss: 243.4854 - val_loss:
208.6227
Epoch 34/400
7/7 [==============================] - 0s 4ms/step - loss: 241.5721 - val_loss:
207.1406
Epoch 35/400
7/7 [==============================] - 0s 4ms/step - loss: 239.3669 - val_loss:
205.9869
Epoch 36/400
7/7 [==============================] - 0s 3ms/step - loss: 237.2800 - val_loss:
204.4895
Epoch 37/400
7/7 [==============================] - 0s 4ms/step - loss: 235.2562 - val_loss:
203.1762
Epoch 38/400
7/7 [==============================] - 0s 4ms/step - loss: 233.3374 - val_loss:
201.7755
Epoch 39/400
7/7 [==============================] - 0s 3ms/step - loss: 231.4808 - val_loss:
200.6095
Epoch 40/400
7/7 [==============================] - 0s 4ms/step - loss: 229.2742 - val_loss:
199.2050
Epoch 41/400
7/7 [==============================] - 0s 4ms/step - loss: 227.3748 - val_loss:
197.7919
Epoch 42/400
7/7 [==============================] - 0s 4ms/step - loss: 225.4486 - val_loss:
196.4147
Epoch 43/400
7/7 [==============================] - 0s 4ms/step - loss: 223.4860 - val_loss:
```

```
195.3155
Epoch 44/400
7/7 [==============================] - 0s 3ms/step - loss: 221.5565 - val_loss:
193.7910
Epoch 45/400
7/7 [==============================] - 0s 3ms/step - loss: 219.9359 - val_loss:
192.2980
Epoch 46/400
7/7 [==============================] - 0s 2ms/step - loss: 217.5161 - val_loss:
190.9313
Epoch 47/400
7/7 [==============================] - 0s 2ms/step - loss: 215.5553 - val_loss:
189.6548
Epoch 48/400
7/7 [==============================] - 0s 3ms/step - loss: 213.7694 - val_loss:
188.0996
Epoch 49/400
7/7 [==============================] - 0s 3ms/step - loss: 211.6036 - val_loss:
186.7313
Epoch 50/400
7/7 [==============================] - 0s 2ms/step - loss: 209.8146 - val_loss:
185.1171
Epoch 51/400
7/7 [==============================] - 0s 3ms/step - loss: 208.1336 - val_loss:
183.8886
Epoch 52/400
7/7 [==============================] - 0s 2ms/step - loss: 205.6571 - val_loss:
182.1450
Epoch 53/400
7/7 [==============================] - 0s 2ms/step - loss: 204.0643 - val_loss:
180.8331
Epoch 54/400
7/7 [==============================] - 0s 2ms/step - loss: 202.1453 - val_loss:
179.3352
Epoch 55/400
7/7 [==============================] - 0s 2ms/step - loss: 199.9961 - val_loss:
177.8587
Epoch 56/400
7/7 [==============================] - 0s 2ms/step - loss: 198.1733 - val_loss:
176.2689
Epoch 57/400
7/7 [==============================] - 0s 2ms/step - loss: 196.2054 - val_loss:
174.9903
Epoch 58/400
7/7 [==============================] - 0s 2ms/step - loss: 194.0042 - val_loss:
173.0806
Epoch 59/400
7/7 [==============================] - 0s 2ms/step - loss: 192.0885 - val_loss:
```

```
171.5199
Epoch 60/400
7/7 [==============================] - 0s 3ms/step - loss: 191.0066 - val_loss:
169.9536
Epoch 61/400
7/7 [==============================] - 0s 3ms/step - loss: 188.1953 - val_loss:
168.8353
Epoch 62/400
7/7 [==============================] - 0s 2ms/step - loss: 186.6008 - val_loss:
167.0987
Epoch 63/400
7/7 [==============================] - 0s 3ms/step - loss: 184.0391 - val_loss:
165.1435
Epoch 64/400
7/7 [==============================] - 0s 3ms/step - loss: 182.3131 - val_loss:
163.3499
Epoch 65/400
7/7 [==============================] - 0s 2ms/step - loss: 180.1909 - val_loss:
161.7340
Epoch 66/400
7/7 [==============================] - 0s 2ms/step - loss: 178.2550 - val_loss:
160.1569
Epoch 67/400
7/7 [==============================] - 0s 3ms/step - loss: 176.3963 - val_loss:
158.2611
Epoch 68/400
7/7 [==============================] - 0s 3ms/step - loss: 174.2777 - val_loss:
156.6418
Epoch 69/400
7/7 [==============================] - 0s 3ms/step - loss: 172.1836 - val_loss:
155.1568
Epoch 70/400
7/7 [==============================] - 0s 3ms/step - loss: 170.3389 - val_loss:
153.3897
Epoch 71/400
7/7 [==============================] - 0s 3ms/step - loss: 168.4413 - val_loss:
151.6374
Epoch 72/400
7/7 [==============================] - 0s 3ms/step - loss: 166.4629 - val_loss:
149.9951
Epoch 73/400
7/7 [==============================] - 0s 3ms/step - loss: 164.5938 - val_loss:
148.2305
Epoch 74/400
7/7 [==============================] - 0s 3ms/step - loss: 162.8541 - val_loss:
146.5357
Epoch 75/400
7/7 [==============================] - 0s 3ms/step - loss: 160.7808 - val_loss:
```

```
144.9496
Epoch 76/400
7/7 [==============================] - 0s 3ms/step - loss: 159.1107 - val_loss:
143.6634
Epoch 77/400
7/7 [==============================] - 0s 2ms/step - loss: 157.4099 - val_loss:
141.5844
Epoch 78/400
7/7 [==============================] - 0s 3ms/step - loss: 155.8779 - val_loss:
139.8398
Epoch 79/400
7/7 [==============================] - 0s 3ms/step - loss: 154.1386 - val_loss:
138.6937
Epoch 80/400
7/7 [==============================] - 0s 3ms/step - loss: 152.3067 - val_loss:
136.7506
Epoch 81/400
7/7 [==============================] - 0s 3ms/step - loss: 151.0710 - val_loss:
135.3559
Epoch 82/400
7/7 [==============================] - 0s 3ms/step - loss: 148.9019 - val_loss:
133.6914
Epoch 83/400
7/7 [==============================] - 0s 3ms/step - loss: 147.5463 - val_loss:
132.2848
Epoch 84/400
7/7 [==============================] - 0s 3ms/step - loss: 145.8955 - val_loss:
131.0391
Epoch 85/400
7/7 [==============================] - 0s 3ms/step - loss: 144.5295 - val_loss:
129.7908
Epoch 86/400
7/7 [==============================] - 0s 3ms/step - loss: 143.4794 - val_loss:
128.1191
Epoch 87/400
7/7 [==============================] - 0s 3ms/step - loss: 141.5528 - val_loss:
127.0783
Epoch 88/400
7/7 [==============================] - 0s 2ms/step - loss: 140.6105 - val_loss:
125.9190
Epoch 89/400
7/7 [==============================] - 0s 2ms/step - loss: 139.1399 - val_loss:
124.2839
Epoch 90/400
7/7 [==============================] - 0s 3ms/step - loss: 138.2433 - val_loss:
123.1145
Epoch 91/400
7/7 [==============================] - 0s 3ms/step - loss: 136.7938 - val_loss:
```

```
122.0843
Epoch 92/400
7/7 [==============================] - 0s 3ms/step - loss: 135.8241 - val_loss:
120.9054
Epoch 93/400
7/7 [==============================] - 0s 2ms/step - loss: 134.7937 - val_loss:
119.7059
Epoch 94/400
7/7 [==============================] - 0s 3ms/step - loss: 133.8536 - val_loss:
118.7402
Epoch 95/400
7/7 [==============================] - 0s 3ms/step - loss: 132.8577 - val_loss:
117.9389
Epoch 96/400
7/7 [==============================] - 0s 3ms/step - loss: 131.9886 - val_loss:
117.4998
Epoch 97/400
7/7 [==============================] - 0s 3ms/step - loss: 131.6762 - val_loss:
116.8827
Epoch 98/400
7/7 [==============================] - 0s 3ms/step - loss: 130.7423 - val_loss:
115.4900
Epoch 99/400
7/7 [==============================] - 0s 2ms/step - loss: 129.8610 - val_loss:
114.6794
Epoch 100/400
7/7 [==============================] - 0s 3ms/step - loss: 129.2363 - val_loss:
113.9424
Epoch 101/400
7/7 [==============================] - 0s 3ms/step - loss: 128.7867 - val_loss:
113.1563
Epoch 102/400
7/7 [==============================] - 0s 3ms/step - loss: 128.0504 - val_loss:
112.4010
Epoch 103/400
7/7 [==============================] - 0s 3ms/step - loss: 127.3686 - val_loss:
112.4061
Epoch 104/400
7/7 [==============================] - 0s 3ms/step - loss: 127.0427 - val_loss:
111.0439
Epoch 105/400
7/7 [==============================] - 0s 3ms/step - loss: 126.3194 - val_loss:
110.3191
Epoch 106/400
7/7 [==============================] - 0s 3ms/step - loss: 125.9844 - val_loss:
110.0899
Epoch 107/400
7/7 [==============================] - 0s 3ms/step - loss: 125.4233 - val_loss:
```

```
109.3381
Epoch 108/400
7/7 [==============================] - 0s 3ms/step - loss: 125.4633 - val_loss:
109.0333
Epoch 109/400
7/7 [==============================] - 0s 3ms/step - loss: 125.0089 - val_loss:
108.8180
Epoch 110/400
7/7 [==============================] - 0s 3ms/step - loss: 124.4438 - val_loss:
108.3338
Epoch 111/400
7/7 [==============================] - 0s 3ms/step - loss: 124.1414 - val_loss:
107.6260
Epoch 112/400
7/7 [==============================] - 0s 2ms/step - loss: 123.5596 - val_loss:
107.5217
Epoch 113/400
7/7 [==============================] - 0s 3ms/step - loss: 123.3877 - val_loss:
107.0661
Epoch 114/400
7/7 [==============================] - 0s 3ms/step - loss: 122.9215 - val_loss:
106.6599
Epoch 115/400
7/7 [==============================] - 0s 3ms/step - loss: 122.7274 - val_loss:
106.3395
Epoch 116/400
7/7 [==============================] - 0s 3ms/step - loss: 122.8673 - val_loss:
106.4488
Epoch 117/400
7/7 [==============================] - 0s 3ms/step - loss: 122.1770 - val_loss:
105.8435
Epoch 118/400
7/7 [==============================] - 0s 3ms/step - loss: 122.0574 - val_loss:
105.5976
Epoch 119/400
7/7 [==============================] - 0s 3ms/step - loss: 121.6610 - val_loss:
105.3705
Epoch 120/400
7/7 [==============================] - 0s 3ms/step - loss: 121.5263 - val_loss:
105.0931
Epoch 121/400
7/7 [==============================] - 0s 2ms/step - loss: 121.3170 - val_loss:
105.1560
Epoch 122/400
7/7 [==============================] - 0s 3ms/step - loss: 121.1066 - val_loss:
104.8355
Epoch 123/400
7/7 [==============================] - 0s 3ms/step - loss: 120.8799 - val_loss:
```

```
104.3817
Epoch 124/400
7/7 [==============================] - 0s 2ms/step - loss: 120.9674 - val_loss:
103.9947
Epoch 125/400
7/7 [==============================] - 0s 2ms/step - loss: 120.4695 - val_loss:
103.6998
Epoch 126/400
7/7 [==============================] - 0s 3ms/step - loss: 120.5310 - val_loss:
103.7300
Epoch 127/400
7/7 [==============================] - 0s 3ms/step - loss: 120.2983 - val_loss:
103.6048
Epoch 128/400
7/7 [==============================] - 0s 2ms/step - loss: 120.0148 - val_loss:
103.5013
Epoch 129/400
7/7 [==============================] - 0s 3ms/step - loss: 119.6008 - val_loss:
103.2005
Epoch 130/400
7/7 [==============================] - 0s 2ms/step - loss: 119.3760 - val_loss:
102.9897
Epoch 131/400
7/7 [==============================] - 0s 2ms/step - loss: 119.4701 - val_loss:
102.7991
Epoch 132/400
7/7 [==============================] - 0s 3ms/step - loss: 119.2064 - val_loss:
102.6226
Epoch 133/400
7/7 [==============================] - 0s 3ms/step - loss: 119.2091 - val_loss:
102.6056
Epoch 134/400
7/7 [==============================] - 0s 3ms/step - loss: 118.7624 - val_loss:
102.6805
Epoch 135/400
7/7 [==============================] - 0s 3ms/step - loss: 118.7571 - val_loss:
102.4441
Epoch 136/400
7/7 [==============================] - 0s 3ms/step - loss: 118.5623 - val_loss:
102.1181
Epoch 137/400
7/7 [==============================] - 0s 3ms/step - loss: 118.6833 - val_loss:
102.0209
Epoch 138/400
7/7 [==============================] - 0s 3ms/step - loss: 118.1970 - val_loss:
102.5767
Epoch 139/400
7/7 [==============================] - 0s 3ms/step - loss: 118.1899 - val_loss:
```

```
101.7306
Epoch 140/400
7/7 [==============================] - 0s 3ms/step - loss: 117.7880 - val_loss:
101.7354
Epoch 141/400
7/7 [==============================] - 0s 3ms/step - loss: 117.6401 - val_loss:
101.7845
Epoch 142/400
7/7 [==============================] - 0s 3ms/step - loss: 117.6804 - val_loss:
101.8476
Epoch 143/400
7/7 [==============================] - 0s 3ms/step - loss: 117.4835 - val_loss:
101.8054
Epoch 144/400
7/7 [==============================] - 0s 3ms/step - loss: 117.2438 - val_loss:
101.9466
Epoch 145/400
7/7 [==============================] - 0s 3ms/step - loss: 117.2037 - val_loss:
101.7458
Epoch 146/400
7/7 [==============================] - 0s 3ms/step - loss: 116.9752 - val_loss:
101.6547
Epoch 147/400
7/7 [==============================] - 0s 2ms/step - loss: 116.9978 - val_loss:
101.7018
Epoch 148/400
7/7 [==============================] - 0s 3ms/step - loss: 116.9963 - val_loss:
101.1999
Epoch 149/400
7/7 [==============================] - 0s 3ms/step - loss: 116.5644 - val_loss:
101.0689
Epoch 150/400
7/7 [==============================] - 0s 3ms/step - loss: 116.6432 - val_loss:
100.8821
Epoch 151/400
7/7 [==============================] - 0s 3ms/step - loss: 116.4585 - val_loss:
100.9799
Epoch 152/400
7/7 [==============================] - 0s 3ms/step - loss: 116.2703 - val_loss:
100.7143
Epoch 153/400
7/7 [==============================] - 0s 3ms/step - loss: 116.0170 - val_loss:
100.5467
Epoch 154/400
7/7 [==============================] - ETA: 0s - loss: 124.591 - 0s 3ms/step -
loss: 116.5486 - val_loss: 100.8119
Epoch 155/400
7/7 [==============================] - 0s 3ms/step - loss: 115.7800 - val_loss:
```

```
100.8745
Epoch 156/400
7/7 [==============================] - 0s 3ms/step - loss: 115.8824 - val_loss:
100.6898
Epoch 157/400
7/7 [==============================] - 0s 3ms/step - loss: 115.9284 - val_loss:
100.6511
Epoch 158/400
7/7 [==============================] - 0s 3ms/step - loss: 115.9786 - val_loss:
100.8680
Epoch 159/400
7/7 [==============================] - 0s 2ms/step - loss: 115.6347 - val_loss:
100.6376
Epoch 160/400
7/7 [==============================] - 0s 3ms/step - loss: 115.6261 - val_loss:
100.5243
Epoch 161/400
7/7 [==============================] - 0s 3ms/step - loss: 115.6874 - val_loss:
100.7051
Epoch 162/400
7/7 [==============================] - 0s 3ms/step - loss: 115.6984 - val_loss:
100.3033
Epoch 163/400
7/7 [==============================] - 0s 3ms/step - loss: 115.4427 - val_loss:
100.0319
Epoch 164/400
7/7 [==============================] - 0s 2ms/step - loss: 115.3741 - val_loss:
99.9591
Epoch 165/400
7/7 [==============================] - 0s 2ms/step - loss: 114.7955 - val_loss:
100.1740
Epoch 166/400
7/7 [==============================] - 0s 3ms/step - loss: 114.7028 - val_loss:
100.0317
Epoch 167/400
7/7 [==============================] - 0s 3ms/step - loss: 114.5030 - val_loss:
99.8893
Epoch 168/400
7/7 [==============================] - 0s 3ms/step - loss: 114.4794 - val_loss:
99.5363
Epoch 169/400
7/7 [==============================] - 0s 3ms/step - loss: 114.3814 - val_loss:
99.1881
Epoch 170/400
7/7 [==============================] - 0s 3ms/step - loss: 114.2493 - val_loss:
99.0408
Epoch 171/400
7/7 [==============================] - 0s 3ms/step - loss: 114.1905 - val_loss:
```

```
98.9944
Epoch 172/400
7/7 [==============================] - 0s 3ms/step - loss: 114.2081 - val_loss:
99.0044
Epoch 173/400
7/7 [==============================] - 0s 3ms/step - loss: 113.9425 - val_loss:
99.0950
Epoch 174/400
7/7 [==============================] - 0s 3ms/step - loss: 114.6107 - val_loss:
99.2414
Epoch 175/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0557 - val_loss:
99.3604
Epoch 176/400
7/7 [==============================] - 0s 3ms/step - loss: 113.7880 - val_loss:
98.7656
Epoch 177/400
7/7 [==============================] - 0s 2ms/step - loss: 114.3142 - val_loss:
98.9037
Epoch 178/400
7/7 [==============================] - 0s 3ms/step - loss: 113.2302 - val_loss:
99.1300
Epoch 179/400
7/7 [==============================] - 0s 2ms/step - loss: 113.7585 - val_loss:
98.8580
Epoch 180/400
7/7 [==============================] - 0s 3ms/step - loss: 113.2786 - val_loss:
98.8848
Epoch 181/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9742 - val_loss:
99.0092
Epoch 182/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9401 - val_loss:
98.8508
Epoch 183/400
7/7 [==============================] - 0s 3ms/step - loss: 112.8335 - val_loss:
98.9210
Epoch 184/400
7/7 [==============================] - 0s 3ms/step - loss: 112.8743 - val_loss:
98.8254
Epoch 185/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9394 - val_loss:
98.7566
Epoch 186/400
7/7 [==============================] - 0s 3ms/step - loss: 112.6184 - val_loss:
98.6985
Epoch 187/400
7/7 [==============================] - 0s 3ms/step - loss: 112.4680 - val_loss:
```

```
98.3156
Epoch 188/400
7/7 [==============================] - 0s 2ms/step - loss: 112.7814 - val_loss:
98.0315
Epoch 189/400
7/7 [==============================] - 0s 2ms/step - loss: 112.3063 - val_loss:
98.0323
Epoch 190/400
7/7 [==============================] - 0s 2ms/step - loss: 113.7128 - val_loss:
97.7953
Epoch 191/400
7/7 [==============================] - 0s 3ms/step - loss: 112.2765 - val_loss:
98.2911
Epoch 192/400
7/7 [==============================] - 0s 3ms/step - loss: 112.2661 - val_loss:
97.8559
Epoch 193/400
7/7 [==============================] - 0s 3ms/step - loss: 111.8123 - val_loss:
97.2654
Epoch 194/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7160 - val_loss:
97.1679
Epoch 195/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7149 - val_loss:
97.1494
Epoch 196/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5320 - val_loss:
96.9499
Epoch 197/400
7/7 [==============================] - 0s 3ms/step - loss: 111.3135 - val_loss:
96.9438
Epoch 198/400
7/7 [==============================] - 0s 3ms/step - loss: 111.2236 - val_loss:
97.0808
Epoch 199/400
7/7 [==============================] - 0s 3ms/step - loss: 111.3231 - val_loss:
96.9861
Epoch 200/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9657 - val_loss:
97.1802
Epoch 201/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9148 - val_loss:
97.2308
Epoch 202/400
7/7 [==============================] - 0s 3ms/step - loss: 111.0101 - val_loss:
97.1553
Epoch 203/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7598 - val_loss:
```

```
96.6995
Epoch 204/400
7/7 [==============================] - 0s 2ms/step - loss: 110.4734 - val_loss:
96.5446
Epoch 205/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4183 - val_loss:
96.7957
Epoch 206/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8493 - val_loss:
96.8204
Epoch 207/400
7/7 [==============================] - 0s 3ms/step - loss: 111.3382 - val_loss:
97.0094
Epoch 208/400
7/7 [==============================] - 0s 2ms/step - loss: 110.5615 - val_loss:
96.7574
Epoch 209/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3464 - val_loss:
96.2462
Epoch 210/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6448 - val_loss:
96.2214
Epoch 211/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9212 - val_loss:
96.3184
Epoch 212/400
7/7 [==============================] - ETA: 0s - loss: 119.993 - 0s 3ms/step -
loss: 109.9854 - val_loss: 97.1622
Epoch 213/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6113 - val_loss:
96.3277
Epoch 214/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1761 - val_loss:
96.1389
Epoch 215/400
7/7 [==============================] - 0s 3ms/step - loss: 109.2931 - val_loss:
96.5535
Epoch 216/400
7/7 [==============================] - 0s 3ms/step - loss: 109.3469 - val_loss:
96.1302
Epoch 217/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0726 - val_loss:
95.9751
Epoch 218/400
7/7 [==============================] - 0s 3ms/step - loss: 109.2431 - val_loss:
96.0104
Epoch 219/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0925 - val_loss:
```

```
95.4818
Epoch 220/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6385 - val_loss:
95.6029
Epoch 221/400
7/7 [==============================] - 0s 3ms/step - loss: 108.4135 - val_loss:
95.5804
Epoch 222/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6882 - val_loss:
95.4244
Epoch 223/400
7/7 [==============================] - 0s 3ms/step - loss: 108.3955 - val_loss:
95.3040
Epoch 224/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0723 - val_loss:
95.3229
Epoch 225/400
7/7 [==============================] - 0s 2ms/step - loss: 107.7645 - val_loss:
95.0458
Epoch 226/400
7/7 [==============================] - 0s 3ms/step - loss: 107.7856 - val_loss:
94.7947
Epoch 227/400
7/7 [==============================] - 0s 3ms/step - loss: 107.3238 - val_loss:
94.5866
Epoch 228/400
7/7 [==============================] - 0s 3ms/step - loss: 107.6008 - val_loss:
94.0403
Epoch 229/400
7/7 [==============================] - 0s 3ms/step - loss: 107.4352 - val_loss:
93.8158
Epoch 230/400
7/7 [==============================] - 0s 3ms/step - loss: 107.0347 - val_loss:
94.0409
Epoch 231/400
7/7 [==============================] - 0s 3ms/step - loss: 106.9379 - val_loss:
93.3555
Epoch 232/400
7/7 [==============================] - 0s 3ms/step - loss: 106.4907 - val_loss:
93.1946
Epoch 233/400
7/7 [==============================] - 0s 3ms/step - loss: 106.4226 - val_loss:
92.9262
Epoch 234/400
7/7 [==============================] - 0s 3ms/step - loss: 106.1919 - val_loss:
92.7968
Epoch 235/400
7/7 [==============================] - 0s 3ms/step - loss: 105.5626 - val_loss:
```

```
91.4747
Epoch 236/400
7/7 [==============================] - 0s 3ms/step - loss: 105.6891 - val_loss:
90.6055
Epoch 237/400
7/7 [==============================] - 0s 3ms/step - loss: 105.1622 - val_loss:
91.0568
Epoch 238/400
7/7 [==============================] - 0s 3ms/step - loss: 104.5199 - val_loss:
91.4832
Epoch 239/400
7/7 [==============================] - 0s 3ms/step - loss: 104.4053 - val_loss:
91.5883
Epoch 240/400
7/7 [==============================] - 0s 3ms/step - loss: 103.9955 - val_loss:
91.4006
Epoch 241/400
7/7 [==============================] - 0s 3ms/step - loss: 103.5449 - val_loss:
91.2071
Epoch 242/400
7/7 [==============================] - 0s 3ms/step - loss: 103.4850 - val_loss:
90.9679
Epoch 243/400
7/7 [==============================] - 0s 2ms/step - loss: 102.8936 - val_loss:
90.7689
Epoch 244/400
7/7 [==============================] - 0s 3ms/step - loss: 102.6266 - val_loss:
90.6407
Epoch 245/400
7/7 [==============================] - 0s 3ms/step - loss: 102.2597 - val_loss:
90.5584
Epoch 246/400
7/7 [==============================] - 0s 3ms/step - loss: 101.7716 - val_loss:
90.4132
Epoch 247/400
7/7 [==============================] - 0s 3ms/step - loss: 101.1852 - val_loss:
89.9878
Epoch 248/400
7/7 [==============================] - 0s 3ms/step - loss: 101.7789 - val_loss:
89.3499
Epoch 249/400
7/7 [==============================] - 0s 3ms/step - loss: 100.9783 - val_loss:
89.6475
Epoch 250/400
7/7 [==============================] - 0s 3ms/step - loss: 100.0483 - val_loss:
89.9984
Epoch 251/400
7/7 [==============================] - 0s 3ms/step - loss: 100.1892 - val_loss:
```

```
89.3147
Epoch 252/400
7/7 [==============================] - 0s 3ms/step - loss: 99.9205 - val_loss:
89.4396
Epoch 253/400
7/7 [==============================] - 0s 3ms/step - loss: 98.8058 - val_loss:
88.9826
Epoch 254/400
7/7 [==============================] - 0s 2ms/step - loss: 98.4887 - val_loss:
88.4046
Epoch 255/400
7/7 [==============================] - 0s 3ms/step - loss: 97.9832 - val_loss:
87.5854
Epoch 256/400
7/7 [==============================] - 0s 3ms/step - loss: 97.4439 - val_loss:
87.3010
Epoch 257/400
7/7 [==============================] - 0s 2ms/step - loss: 97.2306 - val_loss:
86.7970
Epoch 258/400
7/7 [==============================] - 0s 3ms/step - loss: 96.7886 - val_loss:
86.3914
Epoch 259/400
7/7 [==============================] - 0s 3ms/step - loss: 96.0977 - val_loss:
86.9061
Epoch 260/400
7/7 [==============================] - 0s 2ms/step - loss: 96.9259 - val_loss:
86.1778
Epoch 261/400
7/7 [==============================] - 0s 3ms/step - loss: 95.4620 - val_loss:
86.2878
Epoch 262/400
7/7 [==============================] - 0s 3ms/step - loss: 94.9261 - val_loss:
86.2120
Epoch 263/400
7/7 [==============================] - 0s 3ms/step - loss: 95.0549 - val_loss:
85.5708
Epoch 264/400
7/7 [==============================] - 0s 3ms/step - loss: 94.9025 - val_loss:
85.8767
Epoch 265/400
7/7 [==============================] - 0s 3ms/step - loss: 93.3052 - val_loss:
86.0480
Epoch 266/400
7/7 [==============================] - 0s 2ms/step - loss: 93.2672 - val_loss:
85.2037
Epoch 267/400
7/7 [==============================] - 0s 3ms/step - loss: 92.9433 - val_loss:
```

```
84.9366
Epoch 268/400
7/7 [==============================] - 0s 3ms/step - loss: 92.8767 - val_loss:
84.4750
Epoch 269/400
7/7 [==============================] - 0s 2ms/step - loss: 92.1378 - val_loss:
84.0281
Epoch 270/400
7/7 [==============================] - 0s 2ms/step - loss: 91.1960 - val_loss:
84.7426
Epoch 271/400
7/7 [==============================] - 0s 3ms/step - loss: 91.2593 - val_loss:
83.8004
Epoch 272/400
7/7 [==============================] - 0s 3ms/step - loss: 91.1279 - val_loss:
83.4313
Epoch 273/400
7/7 [==============================] - 0s 3ms/step - loss: 90.3485 - val_loss:
83.3858
Epoch 274/400
7/7 [==============================] - 0s 2ms/step - loss: 89.7725 - val_loss:
83.4775
Epoch 275/400
7/7 [==============================] - 0s 3ms/step - loss: 89.6015 - val_loss:
82.8408
Epoch 276/400
7/7 [==============================] - 0s 3ms/step - loss: 88.9379 - val_loss:
82.1613
Epoch 277/400
7/7 [==============================] - 0s 2ms/step - loss: 88.9818 - val_loss:
82.5789
Epoch 278/400
7/7 [==============================] - 0s 3ms/step - loss: 88.1092 - val_loss:
81.6165
Epoch 279/400
7/7 [==============================] - 0s 2ms/step - loss: 87.6342 - val_loss:
81.6645
Epoch 280/400
7/7 [==============================] - 0s 3ms/step - loss: 87.1404 - val_loss:
80.9041
Epoch 281/400
7/7 [==============================] - 0s 2ms/step - loss: 87.1222 - val_loss:
81.2830
Epoch 282/400
7/7 [==============================] - 0s 2ms/step - loss: 86.3607 - val_loss:
81.2959
Epoch 283/400
7/7 [==============================] - 0s 3ms/step - loss: 85.9256 - val_loss:
```

```
81.0828
Epoch 284/400
7/7 [==============================] - 0s 3ms/step - loss: 85.5549 - val_loss:
80.6168
Epoch 285/400
7/7 [==============================] - 0s 3ms/step - loss: 85.3956 - val_loss:
80.3645
Epoch 286/400
7/7 [==============================] - 0s 3ms/step - loss: 84.7247 - val_loss:
79.8036
Epoch 287/400
7/7 [==============================] - 0s 2ms/step - loss: 84.4999 - val_loss:
79.4174
Epoch 288/400
7/7 [==============================] - 0s 2ms/step - loss: 84.1555 - val_loss:
79.1473
Epoch 289/400
7/7 [==============================] - 0s 2ms/step - loss: 83.8292 - val_loss:
79.0514
Epoch 290/400
7/7 [==============================] - 0s 2ms/step - loss: 83.2553 - val_loss:
79.1159
Epoch 291/400
7/7 [==============================] - 0s 3ms/step - loss: 82.8390 - val_loss:
78.6595
Epoch 292/400
7/7 [==============================] - 0s 3ms/step - loss: 82.9097 - val_loss:
78.0151
Epoch 293/400
7/7 [==============================] - 0s 3ms/step - loss: 82.1892 - val_loss:
77.5639
Epoch 294/400
7/7 [==============================] - 0s 3ms/step - loss: 82.2355 - val_loss:
76.9743
Epoch 295/400
7/7 [==============================] - 0s 3ms/step - loss: 81.7672 - val_loss:
76.7162
Epoch 296/400
7/7 [==============================] - 0s 3ms/step - loss: 81.0745 - val_loss:
76.3669
Epoch 297/400
7/7 [==============================] - 0s 3ms/step - loss: 80.9640 - val_loss:
76.3285
Epoch 298/400
7/7 [==============================] - 0s 3ms/step - loss: 80.9496 - val_loss:
76.0369
Epoch 299/400
7/7 [==============================] - 0s 2ms/step - loss: 80.5027 - val_loss:
```

```
75.7335
Epoch 300/400
7/7 [==============================] - 0s 3ms/step - loss: 79.6510 - val_loss:
75.6888
Epoch 301/400
7/7 [==============================] - 0s 3ms/step - loss: 79.4783 - val_loss:
75.3675
Epoch 302/400
7/7 [==============================] - 0s 3ms/step - loss: 79.0863 - val_loss:
75.0921
Epoch 303/400
7/7 [==============================] - 0s 3ms/step - loss: 78.7158 - val_loss:
74.4261
Epoch 304/400
7/7 [==============================] - 0s 3ms/step - loss: 78.8327 - val_loss:
73.6808
Epoch 305/400
7/7 [==============================] - 0s 2ms/step - loss: 77.9837 - val_loss:
73.9546
Epoch 306/400
7/7 [==============================] - 0s 2ms/step - loss: 77.9506 - val_loss:
73.0352
Epoch 307/400
7/7 [==============================] - 0s 3ms/step - loss: 77.5786 - val_loss:
72.9317
Epoch 308/400
7/7 [==============================] - 0s 3ms/step - loss: 77.3624 - val_loss:
72.2192
Epoch 309/400
7/7 [==============================] - 0s 3ms/step - loss: 76.6967 - val_loss:
71.8651
Epoch 310/400
7/7 [==============================] - 0s 3ms/step - loss: 76.9859 - val_loss:
72.1807
Epoch 311/400
7/7 [==============================] - 0s 3ms/step - loss: 77.1425 - val_loss:
71.4056
Epoch 312/400
7/7 [==============================] - 0s 3ms/step - loss: 76.1169 - val_loss:
71.7850
Epoch 313/400
7/7 [==============================] - 0s 3ms/step - loss: 76.3196 - val_loss:
70.8786
Epoch 314/400
7/7 [==============================] - 0s 3ms/step - loss: 75.6669 - val_loss:
70.0609
Epoch 315/400
7/7 [==============================] - 0s 3ms/step - loss: 75.9875 - val_loss:
```

```
69.9456
Epoch 316/400
7/7 [==============================] - 0s 3ms/step - loss: 74.4090 - val_loss:
70.0702
Epoch 317/400
7/7 [==============================] - 0s 3ms/step - loss: 74.2366 - val_loss:
69.4949
Epoch 318/400
7/7 [==============================] - 0s 3ms/step - loss: 74.8768 - val_loss:
69.2193
Epoch 319/400
7/7 [==============================] - 0s 3ms/step - loss: 74.2637 - val_loss:
69.1130
Epoch 320/400
7/7 [==============================] - 0s 3ms/step - loss: 73.4111 - val_loss:
68.2046
Epoch 321/400
7/7 [==============================] - 0s 3ms/step - loss: 73.3265 - val_loss:
68.5353
Epoch 322/400
7/7 [==============================] - 0s 3ms/step - loss: 73.3735 - val_loss:
68.3543
Epoch 323/400
7/7 [==============================] - 0s 3ms/step - loss: 72.5717 - val_loss:
67.4873
Epoch 324/400
7/7 [==============================] - 0s 3ms/step - loss: 72.2941 - val_loss:
67.5768
Epoch 325/400
7/7 [==============================] - 0s 3ms/step - loss: 72.0461 - val_loss:
67.1207
Epoch 326/400
7/7 [==============================] - 0s 3ms/step - loss: 71.3009 - val_loss:
66.4007
Epoch 327/400
7/7 [==============================] - 0s 3ms/step - loss: 71.1603 - val_loss:
66.4246
Epoch 328/400
7/7 [==============================] - 0s 3ms/step - loss: 70.8014 - val_loss:
65.8972
Epoch 329/400
7/7 [==============================] - 0s 3ms/step - loss: 70.6427 - val_loss:
65.7042
Epoch 330/400
7/7 [==============================] - 0s 3ms/step - loss: 70.4342 - val_loss:
65.8074
Epoch 331/400
7/7 [==============================] - 0s 3ms/step - loss: 70.0139 - val_loss:
```

```
64.9941
Epoch 332/400
7/7 [==============================] - 0s 3ms/step - loss: 70.5060 - val_loss:
65.9617
Epoch 333/400
7/7 [==============================] - 0s 3ms/step - loss: 69.7129 - val_loss:
65.5244
Epoch 334/400
7/7 [==============================] - 0s 3ms/step - loss: 69.6159 - val_loss:
64.2894
Epoch 335/400
7/7 [==============================] - 0s 3ms/step - loss: 70.3850 - val_loss:
64.0239
Epoch 336/400
7/7 [==============================] - 0s 2ms/step - loss: 68.7456 - val_loss:
63.5303
Epoch 337/400
7/7 [==============================] - 0s 2ms/step - loss: 68.8013 - val_loss:
63.5394
Epoch 338/400
7/7 [==============================] - 0s 3ms/step - loss: 68.5099 - val_loss:
63.7776
Epoch 339/400
7/7 [==============================] - 0s 3ms/step - loss: 68.2973 - val_loss:
63.3850
Epoch 340/400
7/7 [==============================] - 0s 3ms/step - loss: 67.9471 - val_loss:
63.4518
Epoch 341/400
7/7 [==============================] - 0s 3ms/step - loss: 67.6046 - val_loss:
62.3969
Epoch 342/400
7/7 [==============================] - 0s 3ms/step - loss: 67.6959 - val_loss:
62.8076
Epoch 343/400
7/7 [==============================] - 0s 3ms/step - loss: 67.2858 - val_loss:
62.3426
Epoch 344/400
7/7 [==============================] - 0s 3ms/step - loss: 67.2010 - val_loss:
62.6853
Epoch 345/400
7/7 [==============================] - 0s 3ms/step - loss: 67.0752 - val_loss:
61.7281
Epoch 346/400
7/7 [==============================] - 0s 3ms/step - loss: 66.6147 - val_loss:
62.2139
Epoch 347/400
7/7 [==============================] - 0s 3ms/step - loss: 66.3556 - val_loss:
```

```
61.0520
Epoch 348/400
7/7 [==============================] - 0s 3ms/step - loss: 66.2320 - val_loss:
61.4158
Epoch 349/400
7/7 [==============================] - 0s 3ms/step - loss: 65.8748 - val_loss:
61.2798
Epoch 350/400
7/7 [==============================] - 0s 3ms/step - loss: 65.6175 - val_loss:
60.6162
Epoch 351/400
7/7 [==============================] - 0s 3ms/step - loss: 66.2284 - val_loss:
61.8541
Epoch 352/400
7/7 [==============================] - 0s 2ms/step - loss: 65.4651 - val_loss:
60.1766
Epoch 353/400
7/7 [==============================] - 0s 2ms/step - loss: 65.7041 - val_loss:
61.4714
Epoch 354/400
7/7 [==============================] - 0s 3ms/step - loss: 65.4908 - val_loss:
60.4233
Epoch 355/400
7/7 [==============================] - 0s 3ms/step - loss: 64.5345 - val_loss:
60.1702
Epoch 356/400
7/7 [==============================] - 0s 3ms/step - loss: 64.5715 - val_loss:
59.5345
Epoch 357/400
7/7 [==============================] - 0s 3ms/step - loss: 64.1008 - val_loss:
59.7943
Epoch 358/400
7/7 [==============================] - 0s 3ms/step - loss: 64.2538 - val_loss:
59.1220
Epoch 359/400
7/7 [==============================] - 0s 3ms/step - loss: 63.6663 - val_loss:
60.1070
Epoch 360/400
7/7 [==============================] - 0s 3ms/step - loss: 63.7329 - val_loss:
58.9367
Epoch 361/400
7/7 [==============================] - 0s 3ms/step - loss: 63.3421 - val_loss:
58.4465
Epoch 362/400
7/7 [==============================] - 0s 3ms/step - loss: 63.3301 - val_loss:
58.2490
Epoch 363/400
7/7 [==============================] - 0s 3ms/step - loss: 63.6225 - val_loss:
```

```
58.1622
Epoch 364/400
7/7 [==============================] - 0s 3ms/step - loss: 62.7444 - val_loss:
58.4535
Epoch 365/400
7/7 [==============================] - 0s 3ms/step - loss: 62.6069 - val_loss:
58.1950
Epoch 366/400
7/7 [==============================] - 0s 3ms/step - loss: 62.6533 - val_loss:
57.7896
Epoch 367/400
7/7 [==============================] - 0s 3ms/step - loss: 62.7110 - val_loss:
58.0087
Epoch 368/400
7/7 [==============================] - 0s 3ms/step - loss: 62.7637 - val_loss:
57.1784
Epoch 369/400
7/7 [==============================] - 0s 3ms/step - loss: 62.2803 - val_loss:
57.9913
Epoch 370/400
7/7 [==============================] - 0s 3ms/step - loss: 61.9047 - val_loss:
56.9082
Epoch 371/400
7/7 [==============================] - 0s 3ms/step - loss: 61.4185 - val_loss:
57.4152
Epoch 372/400
7/7 [==============================] - 0s 3ms/step - loss: 61.5531 - val_loss:
57.2272
Epoch 373/400
7/7 [==============================] - 0s 3ms/step - loss: 61.6282 - val_loss:
56.7262
Epoch 374/400
7/7 [==============================] - 0s 3ms/step - loss: 61.3779 - val_loss:
56.9816
Epoch 375/400
7/7 [==============================] - 0s 3ms/step - loss: 60.6217 - val_loss:
56.0683
Epoch 376/400
7/7 [==============================] - 0s 3ms/step - loss: 60.6725 - val_loss:
56.4318
Epoch 377/400
7/7 [==============================] - 0s 3ms/step - loss: 60.9652 - val_loss:
55.8165
Epoch 378/400
7/7 [==============================] - 0s 3ms/step - loss: 60.1014 - val_loss:
55.7089
Epoch 379/400
7/7 [==============================] - 0s 3ms/step - loss: 59.8454 - val_loss:
```

```
55.9656
Epoch 380/400
7/7 [==============================] - 0s 3ms/step - loss: 60.1923 - val_loss:
56.4681
Epoch 381/400
7/7 [==============================] - 0s 3ms/step - loss: 60.3103 - val_loss:
54.9711
Epoch 382/400
7/7 [==============================] - 0s 3ms/step - loss: 59.9530 - val_loss:
55.9956
Epoch 383/400
7/7 [==============================] - 0s 3ms/step - loss: 59.8679 - val_loss:
55.0499
Epoch 384/400
7/7 [==============================] - 0s 3ms/step - loss: 59.1369 - val_loss:
55.0686
Epoch 385/400
7/7 [==============================] - 0s 3ms/step - loss: 59.0603 - val_loss:
55.0170
Epoch 386/400
7/7 [==============================] - 0s 3ms/step - loss: 58.7408 - val_loss:
55.0272
Epoch 387/400
7/7 [==============================] - 0s 3ms/step - loss: 59.2589 - val_loss:
53.9469
Epoch 388/400
7/7 [==============================] - 0s 3ms/step - loss: 59.9140 - val_loss:
55.8160
Epoch 389/400
7/7 [==============================] - 0s 3ms/step - loss: 58.9197 - val_loss:
53.3077
Epoch 390/400
7/7 [==============================] - 0s 3ms/step - loss: 58.4732 - val_loss:
55.2850
Epoch 391/400
7/7 [==============================] - 0s 3ms/step - loss: 58.8730 - val_loss:
53.3048
Epoch 392/400
7/7 [==============================] - 0s 3ms/step - loss: 57.9649 - val_loss:
54.2142
Epoch 393/400
7/7 [==============================] - 0s 3ms/step - loss: 57.6945 - val_loss:
55.2248
Epoch 394/400
7/7 [==============================] - 0s 3ms/step - loss: 57.4702 - val_loss:
53.3521
Epoch 395/400
7/7 [==============================] - 0s 3ms/step - loss: 57.6490 - val_loss:
```

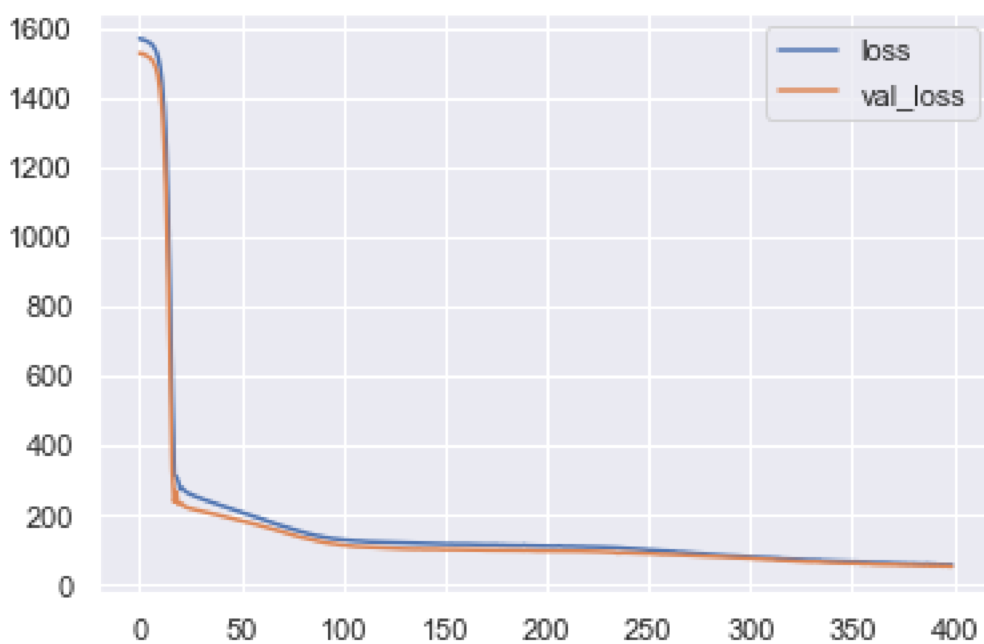
```
54.1252
Epoch 396/400
7/7 [==============================] - 0s 3ms/step - loss: 57.1308 - val_loss:
52.8127
Epoch 397/400
7/7 [==============================] - 0s 3ms/step - loss: 56.8663 - val_loss:
53.9135
Epoch 398/400
7/7 [==============================] - 0s 3ms/step - loss: 56.6674 - val_loss:
53.1033
Epoch 399/400
7/7 [==============================] - 0s 3ms/step - loss: 56.6940 - val_loss:
52.3293
Epoch 400/400
7/7 [==============================] - 0s 3ms/step - loss: 56.4897 - val_loss:
52.8077
```

[35]: <tensorflow.python.keras.callbacks.History at 0x7fe74326d970>

1.5.3 Visualize the Loss Function

[36]:
```
losses = pd.DataFrame(model_2.history.history)
losses.plot()
```

[36]: <matplotlib.axes._subplots.AxesSubplot at 0x7fe743a04820>



Again, we do not observe overfitting on the training data.

1.5.4 Test the Model

[40]:
```
predictions_2 = model_2.predict(X_test)
```

1.5.5 Model Evaluation

[41]:
```
# Model Evaluation Metrics
MAE_2 = mean_absolute_error(y_test,predictions_2)
RMSE_2 = np.sqrt(mean_squared_error(y_test,predictions_2))
EVS_2 = explained_variance_score(y_test,predictions_2)

print('EVALUATION METRICS')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_2}\nRoot Mean Squared Error (RMSE):
→\t\t{RMSE_2}\nExplained Variance Score:\t\t{EVS_2}")
```

```
EVALUATION METRICS
-----------------------------
Mean Absolute Error (MAE):              5.738010522323906
Root Mean Squared Error (RMSE):         7.266889552774522
Explained Variance Score:               0.797885663610966
```

[42]:
```
# Plot Model Predictions (Scatter)
plt.scatter(y_test,predictions_2)

# Plot Perfect predictions (Line)
plt.plot(y_test,y_test,'r')
```

[42]: `[<matplotlib.lines.Line2D at 0x7fe743c7ed90>]`

The variance of our predicted values has been decreased, and our explained variance score has increased significantly. Let us continue with an even deeper neural network below to see if it will increase performance.

1.6 Model 3 - ANN with 20 Hidden Layers

1.6.1 Construct the Artificial Neural Network

[43]:
```
model_3 = Sequential()

# Experiment with 20 hidden layers
model_3.add(Dense(8,activation='relu')) # All layers utilize rectified linear␣
 ↪units (relu)
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
```

```
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(8,activation='relu'))
model_3.add(Dense(4,activation='relu')) # Experiment with number of nodes
model_3.add(Dense(2,activation='relu'))
model_3.add(Dense(1))

model_3.compile(optimizer='adam',loss='mse') # Use the adam optimization␣
 ↪algorithm
```

1.6.2 Train the Model on the Test Data

[44]:
```
model_3.fit(x=X_train,y=y_train.values,
          validation_data=(X_test,y_test.values),
          batch_size=128,epochs=400)
```

```
Epoch 1/400
7/7 [==============================] - 0s 19ms/step - loss: 1568.9457 -
val_loss: 1526.5952
Epoch 2/400
7/7 [==============================] - 0s 3ms/step - loss: 1565.9971 - val_loss:
1523.2644
Epoch 3/400
7/7 [==============================] - 0s 3ms/step - loss: 1562.3982 - val_loss:
1519.1927
Epoch 4/400
7/7 [==============================] - 0s 3ms/step - loss: 1557.9240 - val_loss:
1514.1138
Epoch 5/400
7/7 [==============================] - 0s 3ms/step - loss: 1552.2657 - val_loss:
1507.4445
Epoch 6/400
7/7 [==============================] - 0s 3ms/step - loss: 1544.5946 - val_loss:
1498.2806
Epoch 7/400
7/7 [==============================] - 0s 3ms/step - loss: 1533.9805 - val_loss:
1484.8186
Epoch 8/400
7/7 [==============================] - 0s 3ms/step - loss: 1517.8768 - val_loss:
1463.7943
Epoch 9/400
7/7 [==============================] - 0s 3ms/step - loss: 1491.9983 - val_loss:
1428.6099
Epoch 10/400
7/7 [==============================] - 0s 3ms/step - loss: 1448.0686 - val_loss:
1365.9451
```

```
Epoch 11/400
7/7 [==============================] - 0s 3ms/step - loss: 1367.4667 - val_loss:
1249.4637
Epoch 12/400
7/7 [==============================] - 0s 3ms/step - loss: 1218.5311 - val_loss:
1031.9731
Epoch 13/400
7/7 [==============================] - 0s 3ms/step - loss: 945.0651 - val_loss:
658.5852
Epoch 14/400
7/7 [==============================] - 0s 4ms/step - loss: 540.3538 - val_loss:
259.2043
Epoch 15/400
7/7 [==============================] - 0s 4ms/step - loss: 309.9735 - val_loss:
325.0247
Epoch 16/400
7/7 [==============================] - 0s 4ms/step - loss: 320.4022 - val_loss:
233.2467
Epoch 17/400
7/7 [==============================] - 0s 4ms/step - loss: 278.2654 - val_loss:
243.8734
Epoch 18/400
7/7 [==============================] - 0s 4ms/step - loss: 278.6797 - val_loss:
226.5544
Epoch 19/400
7/7 [==============================] - 0s 3ms/step - loss: 260.2441 - val_loss:
225.4052
Epoch 20/400
7/7 [==============================] - 0s 4ms/step - loss: 259.0803 - val_loss:
220.4627
Epoch 21/400
7/7 [==============================] - 0s 4ms/step - loss: 249.7265 - val_loss:
214.3152
Epoch 22/400
7/7 [==============================] - 0s 4ms/step - loss: 245.3923 - val_loss:
210.5043
Epoch 23/400
7/7 [==============================] - 0s 4ms/step - loss: 239.3511 - val_loss:
208.3407
Epoch 24/400
7/7 [==============================] - 0s 4ms/step - loss: 234.5986 - val_loss:
204.9592
Epoch 25/400
7/7 [==============================] - 0s 4ms/step - loss: 229.9799 - val_loss:
202.7213
Epoch 26/400
7/7 [==============================] - 0s 4ms/step - loss: 225.3479 - val_loss:
198.8309
```

```
Epoch 27/400
7/7 [==============================] - 0s 4ms/step - loss: 221.2529 - val_loss:
195.8791
Epoch 28/400
7/7 [==============================] - 0s 4ms/step - loss: 217.0769 - val_loss:
193.4241
Epoch 29/400
7/7 [==============================] - 0s 4ms/step - loss: 212.8599 - val_loss:
192.0114
Epoch 30/400
7/7 [==============================] - 0s 3ms/step - loss: 209.1808 - val_loss:
188.5977
Epoch 31/400
7/7 [==============================] - 0s 4ms/step - loss: 205.3589 - val_loss:
185.3792
Epoch 32/400
7/7 [==============================] - 0s 4ms/step - loss: 201.0651 - val_loss:
183.9854
Epoch 33/400
7/7 [==============================] - 0s 4ms/step - loss: 197.6430 - val_loss:
180.5126
Epoch 34/400
7/7 [==============================] - 0s 4ms/step - loss: 193.8101 - val_loss:
177.9056
Epoch 35/400
7/7 [==============================] - 0s 4ms/step - loss: 190.3138 - val_loss:
175.5407
Epoch 36/400
7/7 [==============================] - 0s 4ms/step - loss: 187.5989 - val_loss:
173.8006
Epoch 37/400
7/7 [==============================] - 0s 4ms/step - loss: 183.3650 - val_loss:
170.2955
Epoch 38/400
7/7 [==============================] - 0s 4ms/step - loss: 181.0841 - val_loss:
168.0126
Epoch 39/400
7/7 [==============================] - 0s 4ms/step - loss: 177.7159 - val_loss:
166.8676
Epoch 40/400
7/7 [==============================] - 0s 4ms/step - loss: 174.5671 - val_loss:
163.7196
Epoch 41/400
7/7 [==============================] - 0s 4ms/step - loss: 171.8757 - val_loss:
161.8724
Epoch 42/400
7/7 [==============================] - 0s 4ms/step - loss: 169.7774 - val_loss:
160.6930
```

```
Epoch 43/400
7/7 [==============================] - 0s 4ms/step - loss: 166.7750 - val_loss:
157.5111
Epoch 44/400
7/7 [==============================] - 0s 3ms/step - loss: 164.9382 - val_loss:
155.9300
Epoch 45/400
7/7 [==============================] - 0s 3ms/step - loss: 162.6212 - val_loss:
155.1297
Epoch 46/400
7/7 [==============================] - 0s 4ms/step - loss: 159.7703 - val_loss:
151.6433
Epoch 47/400
7/7 [==============================] - 0s 3ms/step - loss: 160.3633 - val_loss:
149.9436
Epoch 48/400
7/7 [==============================] - 0s 4ms/step - loss: 157.7781 - val_loss:
150.5521
Epoch 49/400
7/7 [==============================] - 0s 4ms/step - loss: 154.5367 - val_loss:
146.5264
Epoch 50/400
7/7 [==============================] - 0s 4ms/step - loss: 153.0901 - val_loss:
145.1618
Epoch 51/400
7/7 [==============================] - 0s 4ms/step - loss: 150.8615 - val_loss:
143.7139
Epoch 52/400
7/7 [==============================] - 0s 4ms/step - loss: 150.2802 - val_loss:
142.3002
Epoch 53/400
7/7 [==============================] - 0s 4ms/step - loss: 148.9768 - val_loss:
140.7299
Epoch 54/400
7/7 [==============================] - 0s 4ms/step - loss: 148.5822 - val_loss:
142.5496
Epoch 55/400
7/7 [==============================] - 0s 3ms/step - loss: 145.5343 - val_loss:
138.5043
Epoch 56/400
7/7 [==============================] - 0s 3ms/step - loss: 144.7182 - val_loss:
137.4242
Epoch 57/400
7/7 [==============================] - 0s 3ms/step - loss: 143.5462 - val_loss:
136.9520
Epoch 58/400
7/7 [==============================] - 0s 3ms/step - loss: 141.8042 - val_loss:
134.6312
```

```
Epoch 59/400
7/7 [==============================] - 0s 3ms/step - loss: 140.9669 - val_loss:
133.9775
Epoch 60/400
7/7 [==============================] - 0s 3ms/step - loss: 140.0764 - val_loss:
133.6870
Epoch 61/400
7/7 [==============================] - 0s 3ms/step - loss: 139.4048 - val_loss:
131.3601
Epoch 62/400
7/7 [==============================] - 0s 3ms/step - loss: 138.7475 - val_loss:
131.2758
Epoch 63/400
7/7 [==============================] - 0s 3ms/step - loss: 137.2990 - val_loss:
129.3985
Epoch 64/400
7/7 [==============================] - 0s 3ms/step - loss: 136.3743 - val_loss:
128.8615
Epoch 65/400
7/7 [==============================] - 0s 3ms/step - loss: 135.9345 - val_loss:
127.6312
Epoch 66/400
7/7 [==============================] - 0s 3ms/step - loss: 136.6213 - val_loss:
126.7778
Epoch 67/400
7/7 [==============================] - 0s 3ms/step - loss: 133.5844 - val_loss:
128.2025
Epoch 68/400
7/7 [==============================] - 0s 3ms/step - loss: 134.3612 - val_loss:
125.6385
Epoch 69/400
7/7 [==============================] - 0s 3ms/step - loss: 133.2621 - val_loss:
124.6122
Epoch 70/400
7/7 [==============================] - 0s 3ms/step - loss: 132.6503 - val_loss:
125.0412
Epoch 71/400
7/7 [==============================] - 0s 3ms/step - loss: 132.5237 - val_loss:
122.9496
Epoch 72/400
7/7 [==============================] - 0s 3ms/step - loss: 131.4404 - val_loss:
122.2687
Epoch 73/400
7/7 [==============================] - 0s 3ms/step - loss: 131.0676 - val_loss:
121.2751
Epoch 74/400
7/7 [==============================] - 0s 3ms/step - loss: 130.5962 - val_loss:
121.1824
```

```
Epoch 75/400
7/7 [==============================] - 0s 3ms/step - loss: 130.2103 - val_loss:
119.9016
Epoch 76/400
7/7 [==============================] - 0s 3ms/step - loss: 129.3399 - val_loss:
119.9744
Epoch 77/400
7/7 [==============================] - 0s 3ms/step - loss: 128.6826 - val_loss:
118.8452
Epoch 78/400
7/7 [==============================] - 0s 3ms/step - loss: 128.3559 - val_loss:
118.5415
Epoch 79/400
7/7 [==============================] - 0s 3ms/step - loss: 128.4015 - val_loss:
117.7335
Epoch 80/400
7/7 [==============================] - 0s 3ms/step - loss: 128.1685 - val_loss:
118.0002
Epoch 81/400
7/7 [==============================] - 0s 3ms/step - loss: 127.6152 - val_loss:
116.6069
Epoch 82/400
7/7 [==============================] - 0s 3ms/step - loss: 127.2043 - val_loss:
116.8624
Epoch 83/400
7/7 [==============================] - 0s 3ms/step - loss: 126.2456 - val_loss:
115.6338
Epoch 84/400
7/7 [==============================] - 0s 3ms/step - loss: 126.1515 - val_loss:
115.3544
Epoch 85/400
7/7 [==============================] - 0s 3ms/step - loss: 125.4290 - val_loss:
114.3140
Epoch 86/400
7/7 [==============================] - 0s 3ms/step - loss: 125.4252 - val_loss:
113.9245
Epoch 87/400
7/7 [==============================] - 0s 3ms/step - loss: 124.9064 - val_loss:
113.5773
Epoch 88/400
7/7 [==============================] - 0s 3ms/step - loss: 124.4475 - val_loss:
113.8418
Epoch 89/400
7/7 [==============================] - 0s 3ms/step - loss: 124.2777 - val_loss:
112.5991
Epoch 90/400
7/7 [==============================] - 0s 3ms/step - loss: 123.6858 - val_loss:
112.2939
```

```
Epoch 91/400
7/7 [==============================] - 0s 3ms/step - loss: 123.6286 - val_loss:
111.9269
Epoch 92/400
7/7 [==============================] - 0s 3ms/step - loss: 123.0916 - val_loss:
111.5698
Epoch 93/400
7/7 [==============================] - 0s 3ms/step - loss: 122.7479 - val_loss:
111.7115
Epoch 94/400
7/7 [==============================] - 0s 3ms/step - loss: 122.5583 - val_loss:
110.9570
Epoch 95/400
7/7 [==============================] - 0s 3ms/step - loss: 122.4696 - val_loss:
110.4606
Epoch 96/400
7/7 [==============================] - 0s 3ms/step - loss: 122.6071 - val_loss:
110.9633
Epoch 97/400
7/7 [==============================] - 0s 3ms/step - loss: 121.6371 - val_loss:
109.9210
Epoch 98/400
7/7 [==============================] - 0s 3ms/step - loss: 121.7876 - val_loss:
109.4623
Epoch 99/400
7/7 [==============================] - 0s 3ms/step - loss: 121.5619 - val_loss:
109.8661
Epoch 100/400
7/7 [==============================] - 0s 3ms/step - loss: 121.4002 - val_loss:
109.0219
Epoch 101/400
7/7 [==============================] - 0s 3ms/step - loss: 120.7958 - val_loss:
108.8991
Epoch 102/400
7/7 [==============================] - 0s 3ms/step - loss: 121.9823 - val_loss:
108.4894
Epoch 103/400
7/7 [==============================] - 0s 3ms/step - loss: 120.9180 - val_loss:
108.3575
Epoch 104/400
7/7 [==============================] - 0s 3ms/step - loss: 120.9845 - val_loss:
108.7604
Epoch 105/400
7/7 [==============================] - 0s 3ms/step - loss: 119.9949 - val_loss:
108.0519
Epoch 106/400
7/7 [==============================] - 0s 3ms/step - loss: 119.7349 - val_loss:
107.8850
```

```
Epoch 107/400
7/7 [==============================] - 0s 3ms/step - loss: 120.3151 - val_loss:
107.0381
Epoch 108/400
7/7 [==============================] - 0s 3ms/step - loss: 119.4132 - val_loss:
106.8268
Epoch 109/400
7/7 [==============================] - 0s 3ms/step - loss: 119.2130 - val_loss:
106.6754
Epoch 110/400
7/7 [==============================] - 0s 3ms/step - loss: 118.8162 - val_loss:
106.4168
Epoch 111/400
7/7 [==============================] - 0s 3ms/step - loss: 119.2146 - val_loss:
105.9872
Epoch 112/400
7/7 [==============================] - 0s 3ms/step - loss: 120.8885 - val_loss:
105.8090
Epoch 113/400
7/7 [==============================] - 0s 3ms/step - loss: 118.7144 - val_loss:
105.9745
Epoch 114/400
7/7 [==============================] - 0s 3ms/step - loss: 118.2057 - val_loss:
106.0590
Epoch 115/400
7/7 [==============================] - 0s 3ms/step - loss: 118.1858 - val_loss:
105.0715
Epoch 116/400
7/7 [==============================] - 0s 3ms/step - loss: 118.2854 - val_loss:
104.8135
Epoch 117/400
7/7 [==============================] - 0s 3ms/step - loss: 117.4810 - val_loss:
104.6433
Epoch 118/400
7/7 [==============================] - 0s 3ms/step - loss: 117.5466 - val_loss:
104.4528
Epoch 119/400
7/7 [==============================] - 0s 3ms/step - loss: 117.4035 - val_loss:
104.0713
Epoch 120/400
7/7 [==============================] - 0s 3ms/step - loss: 117.1335 - val_loss:
103.9863
Epoch 121/400
7/7 [==============================] - 0s 3ms/step - loss: 117.1836 - val_loss:
104.1757
Epoch 122/400
7/7 [==============================] - 0s 3ms/step - loss: 116.9883 - val_loss:
103.6448
```

```
Epoch 123/400
7/7 [==============================] - 0s 3ms/step - loss: 116.6264 - val_loss:
103.8672
Epoch 124/400
7/7 [==============================] - 0s 3ms/step - loss: 116.8430 - val_loss:
103.4464
Epoch 125/400
7/7 [==============================] - 0s 3ms/step - loss: 117.5806 - val_loss:
103.1211
Epoch 126/400
7/7 [==============================] - 0s 3ms/step - loss: 117.0773 - val_loss:
103.0830
Epoch 127/400
7/7 [==============================] - 0s 3ms/step - loss: 116.3977 - val_loss:
102.8191
Epoch 128/400
7/7 [==============================] - 0s 3ms/step - loss: 116.1806 - val_loss:
102.8078
Epoch 129/400
7/7 [==============================] - 0s 3ms/step - loss: 116.6213 - val_loss:
102.5905
Epoch 130/400
7/7 [==============================] - 0s 3ms/step - loss: 116.7685 - val_loss:
102.4652
Epoch 131/400
7/7 [==============================] - 0s 3ms/step - loss: 116.6976 - val_loss:
102.2805
Epoch 132/400
7/7 [==============================] - 0s 3ms/step - loss: 116.8498 - val_loss:
102.6015
Epoch 133/400
7/7 [==============================] - 0s 3ms/step - loss: 115.7542 - val_loss:
102.8718
Epoch 134/400
7/7 [==============================] - 0s 3ms/step - loss: 115.5241 - val_loss:
102.4702
Epoch 135/400
7/7 [==============================] - 0s 3ms/step - loss: 115.7314 - val_loss:
101.8374
Epoch 136/400
7/7 [==============================] - 0s 3ms/step - loss: 116.2712 - val_loss:
101.7645
Epoch 137/400
7/7 [==============================] - 0s 3ms/step - loss: 115.0389 - val_loss:
101.9071
Epoch 138/400
7/7 [==============================] - 0s 3ms/step - loss: 115.1872 - val_loss:
101.4058
```

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Epoch 139/400
7/7 [==============================] - 0s 3ms/step - loss: 114.9794 - val_loss:
101.8231
Epoch 140/400
7/7 [==============================] - 0s 3ms/step - loss: 115.6672 - val_loss:
101.2218
Epoch 141/400
7/7 [==============================] - 0s 3ms/step - loss: 117.1093 - val_loss:
101.7328
Epoch 142/400
7/7 [==============================] - 0s 3ms/step - loss: 115.9969 - val_loss:
102.2211
Epoch 143/400
7/7 [==============================] - 0s 3ms/step - loss: 114.9193 - val_loss:
101.5687
Epoch 144/400
7/7 [==============================] - 0s 3ms/step - loss: 115.0195 - val_loss:
101.0305
Epoch 145/400
7/7 [==============================] - 0s 3ms/step - loss: 114.4468 - val_loss:
101.1117
Epoch 146/400
7/7 [==============================] - 0s 3ms/step - loss: 114.5656 - val_loss:
100.7643
Epoch 147/400
7/7 [==============================] - 0s 3ms/step - loss: 116.7583 - val_loss:
100.3499
Epoch 148/400
7/7 [==============================] - 0s 3ms/step - loss: 115.4631 - val_loss:
100.3305
Epoch 149/400
7/7 [==============================] - 0s 3ms/step - loss: 114.3486 - val_loss:
100.3868
Epoch 150/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0658 - val_loss:
100.1590
Epoch 151/400
7/7 [==============================] - 0s 3ms/step - loss: 114.1912 - val_loss:
100.4196
Epoch 152/400
7/7 [==============================] - 0s 3ms/step - loss: 114.6606 - val_loss:
100.3145
Epoch 153/400
7/7 [==============================] - 0s 3ms/step - loss: 114.8169 - val_loss:
100.1319
Epoch 154/400
7/7 [==============================] - 0s 3ms/step - loss: 113.9144 - val_loss:
99.9895
```

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Epoch 155/400
7/7 [==============================] - 0s 3ms/step - loss: 114.2163 - val_loss:
99.8626
Epoch 156/400
7/7 [==============================] - 0s 3ms/step - loss: 113.4813 - val_loss:
99.9121
Epoch 157/400
7/7 [==============================] - 0s 3ms/step - loss: 113.6202 - val_loss:
99.7955
Epoch 158/400
7/7 [==============================] - 0s 3ms/step - loss: 113.5529 - val_loss:
99.9919
Epoch 159/400
7/7 [==============================] - 0s 3ms/step - loss: 113.3484 - val_loss:
100.0878
Epoch 160/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0792 - val_loss:
99.8900
Epoch 161/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0907 - val_loss:
99.7452
Epoch 162/400
7/7 [==============================] - 0s 3ms/step - loss: 113.3528 - val_loss:
99.4975
Epoch 163/400
7/7 [==============================] - 0s 3ms/step - loss: 113.5492 - val_loss:
99.4377
Epoch 164/400
7/7 [==============================] - 0s 3ms/step - loss: 114.4651 - val_loss:
99.6511
Epoch 165/400
7/7 [==============================] - 0s 3ms/step - loss: 115.6763 - val_loss:
99.7146
Epoch 166/400
7/7 [==============================] - 0s 3ms/step - loss: 113.9110 - val_loss:
100.0259
Epoch 167/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9944 - val_loss:
99.4759
Epoch 168/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9036 - val_loss:
99.4911
Epoch 169/400
7/7 [==============================] - 0s 3ms/step - loss: 112.7131 - val_loss:
99.3961
Epoch 170/400
7/7 [==============================] - 0s 3ms/step - loss: 112.6853 - val_loss:
99.3446
```

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Epoch 171/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9471 - val_loss:
99.3381
Epoch 172/400
7/7 [==============================] - 0s 3ms/step - loss: 113.3167 - val_loss:
99.2032
Epoch 173/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0681 - val_loss:
99.2418
Epoch 174/400
7/7 [==============================] - 0s 3ms/step - loss: 112.7225 - val_loss:
99.9449
Epoch 175/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0529 - val_loss:
99.5375
Epoch 176/400
7/7 [==============================] - 0s 3ms/step - loss: 112.9826 - val_loss:
98.4372
Epoch 177/400
7/7 [==============================] - 0s 3ms/step - loss: 112.5422 - val_loss:
98.0723
Epoch 178/400
7/7 [==============================] - 0s 3ms/step - loss: 112.2017 - val_loss:
97.9838
Epoch 179/400
7/7 [==============================] - 0s 3ms/step - loss: 112.3814 - val_loss:
97.8686
Epoch 180/400
7/7 [==============================] - 0s 3ms/step - loss: 113.1275 - val_loss:
97.9603
Epoch 181/400
7/7 [==============================] - 0s 3ms/step - loss: 113.9372 - val_loss:
97.7442
Epoch 182/400
7/7 [==============================] - 0s 3ms/step - loss: 112.5768 - val_loss:
97.9899
Epoch 183/400
7/7 [==============================] - 0s 3ms/step - loss: 112.8976 - val_loss:
97.8528
Epoch 184/400
7/7 [==============================] - 0s 3ms/step - loss: 113.5278 - val_loss:
97.9222
Epoch 185/400
7/7 [==============================] - 0s 3ms/step - loss: 114.7334 - val_loss:
97.8222
Epoch 186/400
7/7 [==============================] - 0s 3ms/step - loss: 114.1081 - val_loss:
98.0757
```

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Epoch 187/400
7/7 [==============================] - 0s 3ms/step - loss: 112.3613 - val_loss:
98.4589
Epoch 188/400
7/7 [==============================] - 0s 3ms/step - loss: 114.8066 - val_loss:
98.1157
Epoch 189/400
7/7 [==============================] - 0s 3ms/step - loss: 112.1693 - val_loss:
98.3865
Epoch 190/400
7/7 [==============================] - 0s 3ms/step - loss: 113.5918 - val_loss:
98.0528
Epoch 191/400
7/7 [==============================] - 0s 3ms/step - loss: 113.8551 - val_loss:
97.8639
Epoch 192/400
7/7 [==============================] - 0s 3ms/step - loss: 113.0243 - val_loss:
98.4503
Epoch 193/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9718 - val_loss:
98.6284
Epoch 194/400
7/7 [==============================] - 0s 3ms/step - loss: 113.1254 - val_loss:
97.3569
Epoch 195/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5840 - val_loss:
97.2861
Epoch 196/400
7/7 [==============================] - 0s 3ms/step - loss: 111.8398 - val_loss:
97.3085
Epoch 197/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5320 - val_loss:
97.3930
Epoch 198/400
7/7 [==============================] - 0s 3ms/step - loss: 112.1200 - val_loss:
97.4272
Epoch 199/400
7/7 [==============================] - 0s 3ms/step - loss: 111.8977 - val_loss:
97.3585
Epoch 200/400
7/7 [==============================] - 0s 3ms/step - loss: 113.2494 - val_loss:
97.1109
Epoch 201/400
7/7 [==============================] - 0s 3ms/step - loss: 112.3362 - val_loss:
97.1849
Epoch 202/400
7/7 [==============================] - 0s 3ms/step - loss: 111.2603 - val_loss:
97.7187
```

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Epoch 203/400
7/7 [==============================] - 0s 3ms/step - loss: 112.5123 - val_loss:
97.2351
Epoch 204/400
7/7 [==============================] - 0s 3ms/step - loss: 111.3871 - val_loss:
97.6931
Epoch 205/400
7/7 [==============================] - 0s 3ms/step - loss: 111.1613 - val_loss:
97.4509
Epoch 206/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8677 - val_loss:
97.6902
Epoch 207/400
7/7 [==============================] - 0s 3ms/step - loss: 113.1933 - val_loss:
97.4598
Epoch 208/400
7/7 [==============================] - 0s 3ms/step - loss: 112.8225 - val_loss:
97.2155
Epoch 209/400
7/7 [==============================] - 0s 3ms/step - loss: 112.0091 - val_loss:
97.6105
Epoch 210/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7442 - val_loss:
97.2435
Epoch 211/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5786 - val_loss:
97.9373
Epoch 212/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8628 - val_loss:
97.4237
Epoch 213/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5119 - val_loss:
97.0906
Epoch 214/400
7/7 [==============================] - 0s 3ms/step - loss: 111.0643 - val_loss:
97.3506
Epoch 215/400
7/7 [==============================] - 0s 3ms/step - loss: 111.1514 - val_loss:
96.8717
Epoch 216/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8829 - val_loss:
96.6118
Epoch 217/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7097 - val_loss:
96.5921
Epoch 218/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6220 - val_loss:
96.7165
```

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Epoch 219/400
7/7 [==============================] - 0s 3ms/step - loss: 111.0151 - val_loss:
96.9227
Epoch 220/400
7/7 [==============================] - 0s 3ms/step - loss: 111.3130 - val_loss:
96.5391
Epoch 221/400
7/7 [==============================] - 0s 3ms/step - loss: 113.3324 - val_loss:
96.5592
Epoch 222/400
7/7 [==============================] - 0s 3ms/step - loss: 113.5084 - val_loss:
96.6689
Epoch 223/400
7/7 [==============================] - 0s 3ms/step - loss: 111.0945 - val_loss:
96.6428
Epoch 224/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7283 - val_loss:
96.8996
Epoch 225/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7879 - val_loss:
96.8857
Epoch 226/400
7/7 [==============================] - 0s 3ms/step - loss: 111.1345 - val_loss:
96.9159
Epoch 227/400
7/7 [==============================] - 0s 3ms/step - loss: 112.2711 - val_loss:
96.2893
Epoch 228/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4317 - val_loss:
96.5012
Epoch 229/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7022 - val_loss:
96.1209
Epoch 230/400
7/7 [==============================] - 0s 3ms/step - loss: 111.4430 - val_loss:
96.2599
Epoch 231/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9830 - val_loss:
96.8142
Epoch 232/400
7/7 [==============================] - 0s 3ms/step - loss: 111.9881 - val_loss:
96.0079
Epoch 233/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8989 - val_loss:
95.8849
Epoch 234/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4135 - val_loss:
95.8701
```

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Epoch 235/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9393 - val_loss:
95.9728
Epoch 236/400
7/7 [==============================] - 0s 3ms/step - loss: 111.5109 - val_loss:
96.1136
Epoch 237/400
7/7 [==============================] - 0s 3ms/step - loss: 111.1281 - val_loss:
95.8316
Epoch 238/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4189 - val_loss:
96.2819
Epoch 239/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8609 - val_loss:
96.0669
Epoch 240/400
7/7 [==============================] - 0s 3ms/step - loss: 110.0097 - val_loss:
96.5358
Epoch 241/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3582 - val_loss:
95.8543
Epoch 242/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3557 - val_loss:
96.0032
Epoch 243/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3218 - val_loss:
96.0135
Epoch 244/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7686 - val_loss:
96.0098
Epoch 245/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6533 - val_loss:
96.0178
Epoch 246/400
7/7 [==============================] - 0s 3ms/step - loss: 112.1880 - val_loss:
95.9050
Epoch 247/400
7/7 [==============================] - 0s 3ms/step - loss: 111.2600 - val_loss:
95.9541
Epoch 248/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7039 - val_loss:
96.6794
Epoch 249/400
7/7 [==============================] - 0s 3ms/step - loss: 111.4294 - val_loss:
96.5646
Epoch 250/400
7/7 [==============================] - 0s 3ms/step - loss: 110.0963 - val_loss:
96.8593
```

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Epoch 251/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1720 - val_loss:
96.5974
Epoch 252/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3464 - val_loss:
96.1968
Epoch 253/400
7/7 [==============================] - 0s 3ms/step - loss: 111.2796 - val_loss:
96.3868
Epoch 254/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9681 - val_loss:
96.1871
Epoch 255/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9508 - val_loss:
96.0086
Epoch 256/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3731 - val_loss:
95.8872
Epoch 257/400
7/7 [==============================] - 0s 3ms/step - loss: 109.8305 - val_loss:
96.1096
Epoch 258/400
7/7 [==============================] - 0s 4ms/step - loss: 110.0591 - val_loss:
96.0336
Epoch 259/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3050 - val_loss:
96.0999
Epoch 260/400
7/7 [==============================] - 0s 3ms/step - loss: 110.2693 - val_loss:
95.6770
Epoch 261/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6054 - val_loss:
95.8632
Epoch 262/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7307 - val_loss:
96.1489
Epoch 263/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1613 - val_loss:
95.9381
Epoch 264/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7661 - val_loss:
96.1383
Epoch 265/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1579 - val_loss:
96.1010
Epoch 266/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7237 - val_loss:
96.3845
```

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Epoch 267/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9513 - val_loss:
96.4098
Epoch 268/400
7/7 [==============================] - 0s 3ms/step - loss: 112.0118 - val_loss:
95.9215
Epoch 269/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6905 - val_loss:
95.8596
Epoch 270/400
7/7 [==============================] - 0s 3ms/step - loss: 111.4030 - val_loss:
95.8012
Epoch 271/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6889 - val_loss:
95.8907
Epoch 272/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9682 - val_loss:
95.6458
Epoch 273/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4217 - val_loss:
96.2471
Epoch 274/400
7/7 [==============================] - 0s 3ms/step - loss: 109.8388 - val_loss:
95.8605
Epoch 275/400
7/7 [==============================] - 0s 3ms/step - loss: 111.0919 - val_loss:
95.9027
Epoch 276/400
7/7 [==============================] - 0s 3ms/step - loss: 109.5475 - val_loss:
96.6512
Epoch 277/400
7/7 [==============================] - 0s 3ms/step - loss: 110.5573 - val_loss:
95.7557
Epoch 278/400
7/7 [==============================] - 0s 3ms/step - loss: 110.0084 - val_loss:
96.0911
Epoch 279/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6363 - val_loss:
95.6884
Epoch 280/400
7/7 [==============================] - 0s 3ms/step - loss: 110.9587 - val_loss:
95.8226
Epoch 281/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1964 - val_loss:
95.8467
Epoch 282/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1337 - val_loss:
96.5099
```

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Epoch 283/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7631 - val_loss:
95.5789
Epoch 284/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1231 - val_loss:
96.3463
Epoch 285/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7056 - val_loss:
95.4780
Epoch 286/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9439 - val_loss:
95.8002
Epoch 287/400
7/7 [==============================] - 0s 3ms/step - loss: 109.1455 - val_loss:
95.8917
Epoch 288/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6347 - val_loss:
95.6814
Epoch 289/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1753 - val_loss:
95.6961
Epoch 290/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3970 - val_loss:
95.4657
Epoch 291/400
7/7 [==============================] - 0s 3ms/step - loss: 110.5139 - val_loss:
95.4014
Epoch 292/400
7/7 [==============================] - 0s 3ms/step - loss: 112.7385 - val_loss:
95.3176
Epoch 293/400
7/7 [==============================] - 0s 3ms/step - loss: 112.5768 - val_loss:
95.3693
Epoch 294/400
7/7 [==============================] - 0s 3ms/step - loss: 112.1650 - val_loss:
95.3634
Epoch 295/400
7/7 [==============================] - 0s 3ms/step - loss: 110.8117 - val_loss:
95.6352
Epoch 296/400
7/7 [==============================] - 0s 3ms/step - loss: 110.1341 - val_loss:
95.2616
Epoch 297/400
7/7 [==============================] - 0s 3ms/step - loss: 110.3454 - val_loss:
95.5369
Epoch 298/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4367 - val_loss:
95.5090
```

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Epoch 299/400
7/7 [==============================] - 0s 3ms/step - loss: 113.8225 - val_loss:
95.6734
Epoch 300/400
7/7 [==============================] - 0s 3ms/step - loss: 111.2369 - val_loss:
97.5196
Epoch 301/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7327 - val_loss:
97.2529
Epoch 302/400
7/7 [==============================] - 0s 3ms/step - loss: 110.6143 - val_loss:
95.7763
Epoch 303/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4718 - val_loss:
96.0338
Epoch 304/400
7/7 [==============================] - 0s 3ms/step - loss: 108.9612 - val_loss:
95.6884
Epoch 305/400
7/7 [==============================] - 0s 3ms/step - loss: 110.2913 - val_loss:
95.6209
Epoch 306/400
7/7 [==============================] - 0s 3ms/step - loss: 109.3436 - val_loss:
95.2451
Epoch 307/400
7/7 [==============================] - 0s 3ms/step - loss: 111.7155 - val_loss:
95.2852
Epoch 308/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4575 - val_loss:
95.7279
Epoch 309/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7216 - val_loss:
95.7950
Epoch 310/400
7/7 [==============================] - 0s 3ms/step - loss: 109.2283 - val_loss:
95.5303
Epoch 311/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0736 - val_loss:
95.2600
Epoch 312/400
7/7 [==============================] - 0s 3ms/step - loss: 109.1758 - val_loss:
95.3225
Epoch 313/400
7/7 [==============================] - 0s 3ms/step - loss: 109.1690 - val_loss:
95.9079
Epoch 314/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0372 - val_loss:
95.5264
```

```
Epoch 315/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0774 - val_loss:
95.4280
Epoch 316/400
7/7 [==============================] - 0s 3ms/step - loss: 109.1105 - val_loss:
95.7286
Epoch 317/400
7/7 [==============================] - 0s 3ms/step - loss: 108.9410 - val_loss:
95.3349
Epoch 318/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0384 - val_loss:
95.7625
Epoch 319/400
7/7 [==============================] - 0s 3ms/step - loss: 109.9091 - val_loss:
94.9487
Epoch 320/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4291 - val_loss:
95.0502
Epoch 321/400
7/7 [==============================] - 0s 3ms/step - loss: 108.9572 - val_loss:
95.1230
Epoch 322/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7282 - val_loss:
95.2453
Epoch 323/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7976 - val_loss:
95.2177
Epoch 324/400
7/7 [==============================] - 0s 3ms/step - loss: 109.5184 - val_loss:
94.8899
Epoch 325/400
7/7 [==============================] - 0s 3ms/step - loss: 110.0182 - val_loss:
94.7188
Epoch 326/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7969 - val_loss:
94.6036
Epoch 327/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6987 - val_loss:
94.7908
Epoch 328/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6617 - val_loss:
95.2060
Epoch 329/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4067 - val_loss:
95.1535
Epoch 330/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0250 - val_loss:
95.1778
```

```
Epoch 331/400
7/7 [==============================] - 0s 3ms/step - loss: 108.8527 - val_loss:
94.9863
Epoch 332/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6858 - val_loss:
94.9732
Epoch 333/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5815 - val_loss:
94.7596
Epoch 334/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5241 - val_loss:
94.6337
Epoch 335/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5338 - val_loss:
94.5630
Epoch 336/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6521 - val_loss:
95.0573
Epoch 337/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6943 - val_loss:
95.1235
Epoch 338/400
7/7 [==============================] - 0s 3ms/step - loss: 109.2692 - val_loss:
95.2804
Epoch 339/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7360 - val_loss:
95.3463
Epoch 340/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7857 - val_loss:
95.6430
Epoch 341/400
7/7 [==============================] - 0s 3ms/step - loss: 109.3787 - val_loss:
94.4793
Epoch 342/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5838 - val_loss:
95.6188
Epoch 343/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7063 - val_loss:
94.9766
Epoch 344/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6716 - val_loss:
95.4528
Epoch 345/400
7/7 [==============================] - 0s 3ms/step - loss: 110.5123 - val_loss:
94.9270
Epoch 346/400
7/7 [==============================] - 0s 3ms/step - loss: 109.0875 - val_loss:
94.8311
```

```
Epoch 347/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2110 - val_loss:
95.2963
Epoch 348/400
7/7 [==============================] - 0s 3ms/step - loss: 108.7237 - val_loss:
94.7394
Epoch 349/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6000 - val_loss:
94.9320
Epoch 350/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5122 - val_loss:
94.5451
Epoch 351/400
7/7 [==============================] - 0s 3ms/step - loss: 108.9557 - val_loss:
94.4001
Epoch 352/400
7/7 [==============================] - 0s 3ms/step - loss: 108.8386 - val_loss:
94.3887
Epoch 353/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5723 - val_loss:
94.1661
Epoch 354/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2730 - val_loss:
94.3902
Epoch 355/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2493 - val_loss:
94.1639
Epoch 356/400
7/7 [==============================] - 0s 3ms/step - loss: 108.3180 - val_loss:
94.3452
Epoch 357/400
7/7 [==============================] - 0s 3ms/step - loss: 108.1003 - val_loss:
94.3426
Epoch 358/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0347 - val_loss:
94.7075
Epoch 359/400
7/7 [==============================] - 0s 3ms/step - loss: 108.5242 - val_loss:
94.1667
Epoch 360/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2606 - val_loss:
93.9132
Epoch 361/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0319 - val_loss:
94.3511
Epoch 362/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2866 - val_loss:
94.0218
```

```
Epoch 363/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2857 - val_loss:
94.4790
Epoch 364/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0454 - val_loss:
94.3014
Epoch 365/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4038 - val_loss:
93.9753
Epoch 366/400
7/7 [==============================] - 0s 3ms/step - loss: 109.7802 - val_loss:
93.7848
Epoch 367/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4670 - val_loss:
93.6093
Epoch 368/400
7/7 [==============================] - 0s 3ms/step - loss: 109.4378 - val_loss:
94.1859
Epoch 369/400
7/7 [==============================] - 0s 3ms/step - loss: 109.3071 - val_loss:
94.0445
Epoch 370/400
7/7 [==============================] - 0s 3ms/step - loss: 109.1571 - val_loss:
94.4229
Epoch 371/400
7/7 [==============================] - 0s 3ms/step - loss: 108.8118 - val_loss:
94.0270
Epoch 372/400
7/7 [==============================] - 0s 3ms/step - loss: 110.0400 - val_loss:
94.3858
Epoch 373/400
7/7 [==============================] - 0s 3ms/step - loss: 112.0611 - val_loss:
94.8304
Epoch 374/400
7/7 [==============================] - 0s 3ms/step - loss: 111.6376 - val_loss:
94.6525
Epoch 375/400
7/7 [==============================] - 0s 3ms/step - loss: 110.5461 - val_loss:
94.9383
Epoch 376/400
7/7 [==============================] - 0s 3ms/step - loss: 108.4003 - val_loss:
95.1534
Epoch 377/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0429 - val_loss:
94.3007
Epoch 378/400
7/7 [==============================] - 0s 3ms/step - loss: 107.8698 - val_loss:
94.2014
```

```
Epoch 379/400
7/7 [==============================] - 0s 3ms/step - loss: 108.2114 - val_loss:
93.8799
Epoch 380/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6289 - val_loss:
93.7775
Epoch 381/400
7/7 [==============================] - 0s 3ms/step - loss: 107.6319 - val_loss:
94.2975
Epoch 382/400
7/7 [==============================] - 0s 3ms/step - loss: 108.3656 - val_loss:
93.9851
Epoch 383/400
7/7 [==============================] - 0s 3ms/step - loss: 107.9503 - val_loss:
93.9258
Epoch 384/400
7/7 [==============================] - 0s 3ms/step - loss: 107.5885 - val_loss:
94.1631
Epoch 385/400
7/7 [==============================] - 0s 3ms/step - loss: 107.4992 - val_loss:
94.2064
Epoch 386/400
7/7 [==============================] - 0s 3ms/step - loss: 107.3201 - val_loss:
94.1071
Epoch 387/400
7/7 [==============================] - 0s 3ms/step - loss: 107.6112 - val_loss:
94.0848
Epoch 388/400
7/7 [==============================] - 0s 3ms/step - loss: 107.4504 - val_loss:
93.8705
Epoch 389/400
7/7 [==============================] - 0s 3ms/step - loss: 107.3066 - val_loss:
93.7152
Epoch 390/400
7/7 [==============================] - 0s 3ms/step - loss: 107.5062 - val_loss:
93.6017
Epoch 391/400
7/7 [==============================] - 0s 3ms/step - loss: 107.3806 - val_loss:
93.5495
Epoch 392/400
7/7 [==============================] - 0s 3ms/step - loss: 106.9586 - val_loss:
93.6386
Epoch 393/400
7/7 [==============================] - 0s 3ms/step - loss: 107.9349 - val_loss:
92.9440
Epoch 394/400
7/7 [==============================] - 0s 3ms/step - loss: 106.8667 - val_loss:
93.4834
```

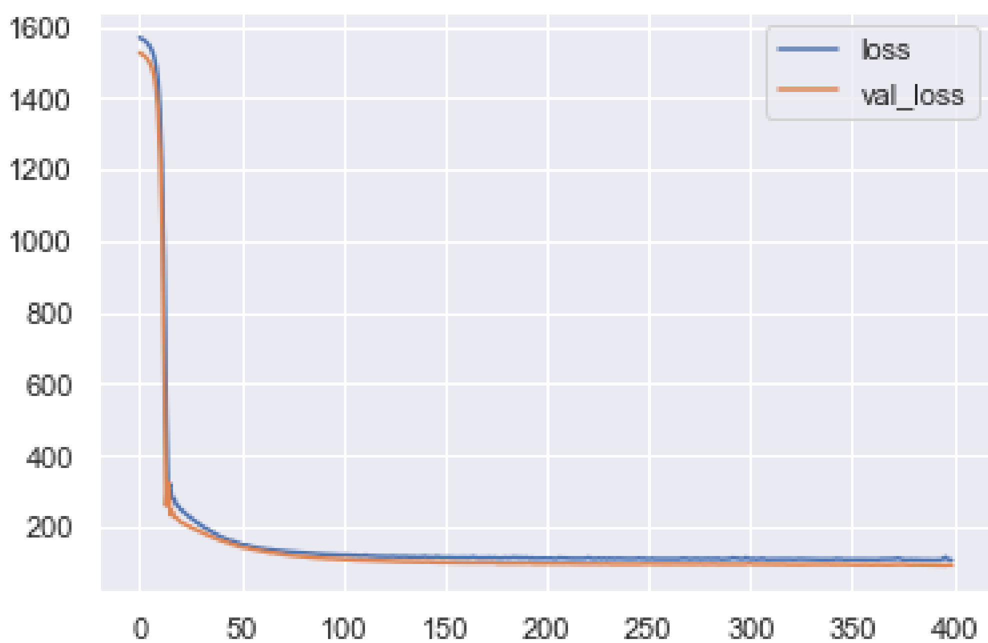
```
Epoch 395/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0449 - val_loss:
92.6760
Epoch 396/400
7/7 [==============================] - 0s 3ms/step - loss: 112.1823 - val_loss:
92.2604
Epoch 397/400
7/7 [==============================] - 0s 3ms/step - loss: 114.9715 - val_loss:
92.2536
Epoch 398/400
7/7 [==============================] - 0s 3ms/step - loss: 109.3427 - val_loss:
92.9420
Epoch 399/400
7/7 [==============================] - 0s 3ms/step - loss: 108.0355 - val_loss:
93.8703
Epoch 400/400
7/7 [==============================] - 0s 3ms/step - loss: 106.6855 - val_loss:
92.5438
```

[44]:
```
<tensorflow.python.keras.callbacks.History at 0x7fe743c45220>
```

1.6.3 Visualize the Loss Function

[45]:
```
losses = pd.DataFrame(model_3.history.history)
losses.plot()
```

[45]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe7445635e0>
```



1.6.4 Test the Model

[46]:
```
predictions_3 = model_3.predict(X_test)
```

1.6.5 Model Evaluation

[50]:
```
# Model Evaluation Metrics
MAE_3 = mean_absolute_error(y_test,predictions_3)
RMSE_3 = np.sqrt(mean_squared_error(y_test,predictions_3))
EVS_3 = explained_variance_score(y_test,predictions_3)

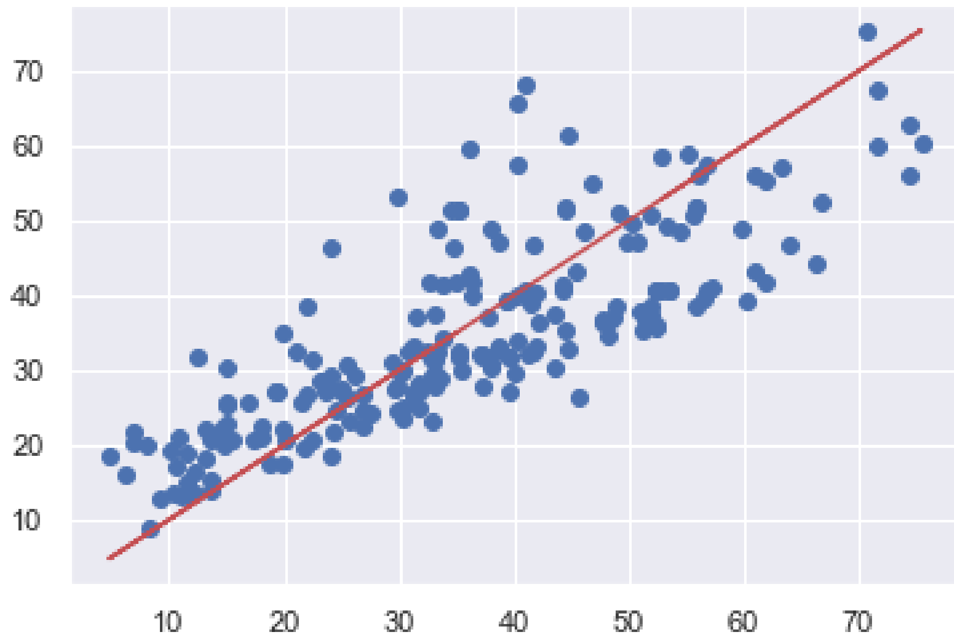
print('EVALUATION METRICS')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_3}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE_3}\nExplained Variance Score:\t\t{EVS_3}")
```

```
EVALUATION METRICS
-----------------------------
Mean Absolute Error (MAE):          7.611444954733247
Root Mean Squared Error (RMSE):     9.619967686192227
Explained Variance Score:           0.6426482928244076
```

[51]:
```
# Plot Model Predictions (Scatter)
plt.scatter(y_test,predictions_3)

# Plot Perfect predictions (Line)
plt.plot(y_test,y_test,'r')
```

[51]:
```
[<matplotlib.lines.Line2D at 0x7fe745807820>]
```



Interesting - we would expect from the loss function that the data was not overfitted. But Our model evaluation metrics are worse with the deeper neural network. It appears that Model 3 has overfitted to the training data.

1.7 Model 4 - ANN with 15 Hidden Layers

1.7.1 Construct the Artificial Neural Network

[52]:
```
model_4 = Sequential()

# Experiment with 15 hidden layers
model_4.add(Dense(8,activation='relu')) # All layers utilize rectified linear␣
↪units (relu)
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(8,activation='relu'))
model_4.add(Dense(4,activation='relu')) # Experiment with number of nodes
```

```
model_4.add(Dense(2,activation='relu'))
model_4.add(Dense(1))

model_4.compile(optimizer='adam',loss='mse') # Use the adam optimization␣
 ↪algorithm
```

1.7.2 Train the Model on the Test Data

[53]:
```
model_4.fit(x=X_train,y=y_train.values,
          validation_data=(X_test,y_test.values),
          batch_size=128,epochs=400)
```

```
Epoch 1/400
7/7 [==============================] - 0s 16ms/step - loss: 1569.6517 -
val_loss: 1528.5724
Epoch 2/400
7/7 [==============================] - 0s 3ms/step - loss: 1568.9656 - val_loss:
1527.8374
Epoch 3/400
7/7 [==============================] - 0s 3ms/step - loss: 1568.1913 - val_loss:
1527.0037
Epoch 4/400
7/7 [==============================] - 0s 3ms/step - loss: 1567.3076 - val_loss:
1526.0594
Epoch 5/400
7/7 [==============================] - 0s 3ms/step - loss: 1566.3008 - val_loss:
1524.9404
Epoch 6/400
7/7 [==============================] - 0s 3ms/step - loss: 1565.0789 - val_loss:
1523.5724
Epoch 7/400
7/7 [==============================] - 0s 3ms/step - loss: 1563.5645 - val_loss:
1521.8213
Epoch 8/400
7/7 [==============================] - 0s 3ms/step - loss: 1561.5829 - val_loss:
1519.4446
Epoch 9/400
7/7 [==============================] - 0s 3ms/step - loss: 1558.8408 - val_loss:
1516.0094
Epoch 10/400
7/7 [==============================] - 0s 3ms/step - loss: 1554.7252 - val_loss:
1510.6748
Epoch 11/400
7/7 [==============================] - 0s 3ms/step - loss: 1548.0762 - val_loss:
1501.3348
Epoch 12/400
7/7 [==============================] - 0s 4ms/step - loss: 1536.1271 - val_loss:
```

```
1483.3419
Epoch 13/400
7/7 [==============================] - 0s 4ms/step - loss: 1512.1233 - val_loss:
1446.5977
Epoch 14/400
7/7 [==============================] - 0s 4ms/step - loss: 1462.8507 - val_loss:
1369.2535
Epoch 15/400
7/7 [==============================] - 0s 4ms/step - loss: 1358.2751 - val_loss:
1209.3948
Epoch 16/400
7/7 [==============================] - 0s 3ms/step - loss: 1151.4575 - val_loss:
902.4726
Epoch 17/400
7/7 [==============================] - 0s 4ms/step - loss: 783.0852 - val_loss:
447.1139
Epoch 18/400
7/7 [==============================] - 0s 4ms/step - loss: 389.2601 - val_loss:
290.0338
Epoch 19/400
7/7 [==============================] - 0s 4ms/step - loss: 382.1864 - val_loss:
282.7052
Epoch 20/400
7/7 [==============================] - 0s 3ms/step - loss: 308.4108 - val_loss:
253.0698
Epoch 21/400
7/7 [==============================] - 0s 4ms/step - loss: 310.2160 - val_loss:
252.3701
Epoch 22/400
7/7 [==============================] - 0s 4ms/step - loss: 293.6807 - val_loss:
233.1269
Epoch 23/400
7/7 [==============================] - 0s 3ms/step - loss: 282.4200 - val_loss:
232.0586
Epoch 24/400
7/7 [==============================] - 0s 3ms/step - loss: 273.9956 - val_loss:
223.9356
Epoch 25/400
7/7 [==============================] - 0s 4ms/step - loss: 266.1599 - val_loss:
219.6889
Epoch 26/400
7/7 [==============================] - 0s 4ms/step - loss: 258.3751 - val_loss:
214.9944
Epoch 27/400
7/7 [==============================] - 0s 4ms/step - loss: 252.2752 - val_loss:
211.0973
Epoch 28/400
7/7 [==============================] - 0s 4ms/step - loss: 246.7562 - val_loss:
```

```
206.8980
Epoch 29/400
7/7 [==============================] - 0s 4ms/step - loss: 241.1620 - val_loss:
203.0097
Epoch 30/400
7/7 [==============================] - 0s 3ms/step - loss: 236.0636 - val_loss:
199.3719
Epoch 31/400
7/7 [==============================] - 0s 4ms/step - loss: 231.0092 - val_loss:
195.8316
Epoch 32/400
7/7 [==============================] - 0s 4ms/step - loss: 226.5097 - val_loss:
192.2419
Epoch 33/400
7/7 [==============================] - 0s 3ms/step - loss: 221.2636 - val_loss:
188.8632
Epoch 34/400
7/7 [==============================] - 0s 4ms/step - loss: 216.8356 - val_loss:
184.6434
Epoch 35/400
7/7 [==============================] - 0s 4ms/step - loss: 211.1097 - val_loss:
180.8664
Epoch 36/400
7/7 [==============================] - 0s 3ms/step - loss: 206.3285 - val_loss:
176.9061
Epoch 37/400
7/7 [==============================] - 0s 4ms/step - loss: 202.3532 - val_loss:
172.6709
Epoch 38/400
7/7 [==============================] - 0s 3ms/step - loss: 197.0275 - val_loss:
168.4651
Epoch 39/400
7/7 [==============================] - 0s 3ms/step - loss: 192.2916 - val_loss:
163.8840
Epoch 40/400
7/7 [==============================] - 0s 4ms/step - loss: 187.1704 - val_loss:
158.8861
Epoch 41/400
7/7 [==============================] - 0s 3ms/step - loss: 182.2265 - val_loss:
153.9319
Epoch 42/400
7/7 [==============================] - 0s 4ms/step - loss: 176.5257 - val_loss:
148.6303
Epoch 43/400
7/7 [==============================] - 0s 4ms/step - loss: 170.5932 - val_loss:
142.8735
Epoch 44/400
7/7 [==============================] - 0s 4ms/step - loss: 165.0470 - val_loss:
```

```
136.8508
Epoch 45/400
7/7 [==============================] - 0s 3ms/step - loss: 159.2249 - val_loss:
132.4601
Epoch 46/400
7/7 [==============================] - 0s 4ms/step - loss: 154.8795 - val_loss:
126.6207
Epoch 47/400
7/7 [==============================] - 0s 4ms/step - loss: 148.3882 - val_loss:
122.8430
Epoch 48/400
7/7 [==============================] - 0s 3ms/step - loss: 144.2979 - val_loss:
118.8344
Epoch 49/400
7/7 [==============================] - 0s 4ms/step - loss: 140.1117 - val_loss:
115.7323
Epoch 50/400
7/7 [==============================] - 0s 4ms/step - loss: 136.2878 - val_loss:
113.1091
Epoch 51/400
7/7 [==============================] - 0s 4ms/step - loss: 133.0580 - val_loss:
110.4724
Epoch 52/400
7/7 [==============================] - 0s 4ms/step - loss: 130.0017 - val_loss:
108.6249
Epoch 53/400
7/7 [==============================] - 0s 3ms/step - loss: 127.5810 - val_loss:
106.6511
Epoch 54/400
7/7 [==============================] - 0s 4ms/step - loss: 125.3233 - val_loss:
105.4246
Epoch 55/400
7/7 [==============================] - 0s 4ms/step - loss: 124.1945 - val_loss:
104.0983
Epoch 56/400
7/7 [==============================] - 0s 3ms/step - loss: 122.3161 - val_loss:
103.5813
Epoch 57/400
7/7 [==============================] - 0s 3ms/step - loss: 120.6602 - val_loss:
102.2931
Epoch 58/400
7/7 [==============================] - 0s 3ms/step - loss: 120.1138 - val_loss:
102.1570
Epoch 59/400
7/7 [==============================] - 0s 3ms/step - loss: 118.0651 - val_loss:
100.9484
Epoch 60/400
7/7 [==============================] - 0s 3ms/step - loss: 117.4444 - val_loss:
```

```
100.1003
Epoch 61/400
7/7 [==============================] - 0s 3ms/step - loss: 116.3090 - val_loss:
99.3473
Epoch 62/400
7/7 [==============================] - 0s 3ms/step - loss: 116.3277 - val_loss:
98.5844
Epoch 63/400
7/7 [==============================] - 0s 3ms/step - loss: 114.5209 - val_loss:
98.6674
Epoch 64/400
7/7 [==============================] - 0s 3ms/step - loss: 114.4626 - val_loss:
97.6782
Epoch 65/400
7/7 [==============================] - 0s 3ms/step - loss: 114.0327 - val_loss:
97.6411
Epoch 66/400
7/7 [==============================] - 0s 3ms/step - loss: 112.4332 - val_loss:
97.3358
Epoch 67/400
7/7 [==============================] - 0s 3ms/step - loss: 112.6499 - val_loss:
96.3799
Epoch 68/400
7/7 [==============================] - 0s 3ms/step - loss: 111.6824 - val_loss:
96.1720
Epoch 69/400
7/7 [==============================] - 0s 3ms/step - loss: 112.0133 - val_loss:
95.7298
Epoch 70/400
7/7 [==============================] - 0s 3ms/step - loss: 110.7370 - val_loss:
95.3371
Epoch 71/400
7/7 [==============================] - 0s 3ms/step - loss: 110.4582 - val_loss:
95.0931
Epoch 72/400
7/7 [==============================] - 0s 3ms/step - loss: 109.8978 - val_loss:
94.3576
Epoch 73/400
7/7 [==============================] - 0s 3ms/step - loss: 109.6889 - val_loss:
94.9939
Epoch 74/400
7/7 [==============================] - 0s 3ms/step - loss: 108.9073 - val_loss:
93.7686
Epoch 75/400
7/7 [==============================] - 0s 3ms/step - loss: 108.6104 - val_loss:
93.1857
Epoch 76/400
7/7 [==============================] - 0s 3ms/step - loss: 107.7745 - val_loss:
```

```
92.9079
Epoch 77/400
7/7 [==============================] - 0s 3ms/step - loss: 107.0518 - val_loss:
92.2739
Epoch 78/400
7/7 [==============================] - 0s 3ms/step - loss: 106.8930 - val_loss:
91.9535
Epoch 79/400
7/7 [==============================] - 0s 3ms/step - loss: 107.1325 - val_loss:
91.3619
Epoch 80/400
7/7 [==============================] - 0s 3ms/step - loss: 105.9684 - val_loss:
91.8785
Epoch 81/400
7/7 [==============================] - 0s 3ms/step - loss: 105.5228 - val_loss:
91.3594
Epoch 82/400
7/7 [==============================] - 0s 3ms/step - loss: 105.2764 - val_loss:
90.8102
Epoch 83/400
7/7 [==============================] - 0s 3ms/step - loss: 104.2794 - val_loss:
90.4847
Epoch 84/400
7/7 [==============================] - 0s 3ms/step - loss: 104.0304 - val_loss:
89.8474
Epoch 85/400
7/7 [==============================] - 0s 3ms/step - loss: 103.4136 - val_loss:
89.3449
Epoch 86/400
7/7 [==============================] - 0s 3ms/step - loss: 102.8306 - val_loss:
88.9763
Epoch 87/400
7/7 [==============================] - 0s 3ms/step - loss: 102.5051 - val_loss:
88.4824
Epoch 88/400
7/7 [==============================] - 0s 3ms/step - loss: 102.2045 - val_loss:
88.0458
Epoch 89/400
7/7 [==============================] - 0s 3ms/step - loss: 101.4275 - val_loss:
87.8621
Epoch 90/400
7/7 [==============================] - 0s 3ms/step - loss: 101.1706 - val_loss:
87.3873
Epoch 91/400
7/7 [==============================] - 0s 3ms/step - loss: 100.5588 - val_loss:
86.3990
Epoch 92/400
7/7 [==============================] - 0s 3ms/step - loss: 100.1059 - val_loss:
```

```
85.7669
Epoch 93/400
7/7 [==============================] - 0s 3ms/step - loss: 99.4280 - val_loss:
85.3662
Epoch 94/400
7/7 [==============================] - 0s 3ms/step - loss: 99.0385 - val_loss:
85.0207
Epoch 95/400
7/7 [==============================] - 0s 3ms/step - loss: 98.3995 - val_loss:
84.5055
Epoch 96/400
7/7 [==============================] - 0s 3ms/step - loss: 97.9412 - val_loss:
83.9207
Epoch 97/400
7/7 [==============================] - 0s 3ms/step - loss: 97.9145 - val_loss:
83.2244
Epoch 98/400
7/7 [==============================] - 0s 3ms/step - loss: 97.5608 - val_loss:
82.9134
Epoch 99/400
7/7 [==============================] - 0s 3ms/step - loss: 95.9689 - val_loss:
82.7603
Epoch 100/400
7/7 [==============================] - 0s 3ms/step - loss: 96.2566 - val_loss:
81.6754
Epoch 101/400
7/7 [==============================] - 0s 3ms/step - loss: 95.5922 - val_loss:
81.3458
Epoch 102/400
7/7 [==============================] - 0s 3ms/step - loss: 94.3719 - val_loss:
80.7655
Epoch 103/400
7/7 [==============================] - 0s 3ms/step - loss: 94.1444 - val_loss:
79.9830
Epoch 104/400
7/7 [==============================] - 0s 3ms/step - loss: 93.5438 - val_loss:
79.1865
Epoch 105/400
7/7 [==============================] - 0s 3ms/step - loss: 92.2635 - val_loss:
77.9169
Epoch 106/400
7/7 [==============================] - 0s 3ms/step - loss: 90.7175 - val_loss:
76.6562
Epoch 107/400
7/7 [==============================] - 0s 3ms/step - loss: 89.8815 - val_loss:
75.1235
Epoch 108/400
7/7 [==============================] - 0s 3ms/step - loss: 88.5678 - val_loss:
```

```
74.0828
Epoch 109/400
7/7 [==============================] - 0s 3ms/step - loss: 87.7763 - val_loss:
72.5612
Epoch 110/400
7/7 [==============================] - 0s 3ms/step - loss: 86.5197 - val_loss:
72.2569
Epoch 111/400
7/7 [==============================] - 0s 3ms/step - loss: 85.0934 - val_loss:
71.2570
Epoch 112/400
7/7 [==============================] - 0s 3ms/step - loss: 84.1005 - val_loss:
70.4560
Epoch 113/400
7/7 [==============================] - 0s 3ms/step - loss: 82.9871 - val_loss:
69.4554
Epoch 114/400
7/7 [==============================] - 0s 3ms/step - loss: 82.2355 - val_loss:
69.0550
Epoch 115/400
7/7 [==============================] - 0s 3ms/step - loss: 81.5095 - val_loss:
68.9941
Epoch 116/400
7/7 [==============================] - 0s 3ms/step - loss: 79.7304 - val_loss:
67.8163
Epoch 117/400
7/7 [==============================] - 0s 3ms/step - loss: 79.5815 - val_loss:
67.4640
Epoch 118/400
7/7 [==============================] - 0s 3ms/step - loss: 79.0065 - val_loss:
66.4543
Epoch 119/400
7/7 [==============================] - 0s 3ms/step - loss: 77.9885 - val_loss:
65.7818
Epoch 120/400
7/7 [==============================] - 0s 3ms/step - loss: 76.9187 - val_loss:
65.8063
Epoch 121/400
7/7 [==============================] - 0s 3ms/step - loss: 76.9349 - val_loss:
64.8729
Epoch 122/400
7/7 [==============================] - 0s 3ms/step - loss: 76.1170 - val_loss:
65.5652
Epoch 123/400
7/7 [==============================] - 0s 3ms/step - loss: 75.8183 - val_loss:
64.6070
Epoch 124/400
7/7 [==============================] - 0s 3ms/step - loss: 74.3393 - val_loss:
```

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63.8343
Epoch 125/400
7/7 [==============================] - 0s 3ms/step - loss: 74.3577 - val_loss:
64.1022
Epoch 126/400
7/7 [==============================] - 0s 3ms/step - loss: 73.7784 - val_loss:
63.5339
Epoch 127/400
7/7 [==============================] - 0s 3ms/step - loss: 72.8414 - val_loss:
64.0992
Epoch 128/400
7/7 [==============================] - 0s 3ms/step - loss: 72.5799 - val_loss:
63.1678
Epoch 129/400
7/7 [==============================] - 0s 3ms/step - loss: 71.9635 - val_loss:
63.0343
Epoch 130/400
7/7 [==============================] - 0s 3ms/step - loss: 71.4762 - val_loss:
62.3366
Epoch 131/400
7/7 [==============================] - 0s 3ms/step - loss: 71.1892 - val_loss:
61.9465
Epoch 132/400
7/7 [==============================] - 0s 3ms/step - loss: 70.9985 - val_loss:
62.1998
Epoch 133/400
7/7 [==============================] - 0s 3ms/step - loss: 70.9429 - val_loss:
61.6267
Epoch 134/400
7/7 [==============================] - 0s 3ms/step - loss: 70.7419 - val_loss:
61.7030
Epoch 135/400
7/7 [==============================] - 0s 3ms/step - loss: 70.2983 - val_loss:
61.2276
Epoch 136/400
7/7 [==============================] - 0s 3ms/step - loss: 71.3225 - val_loss:
61.0671
Epoch 137/400
7/7 [==============================] - 0s 3ms/step - loss: 69.4086 - val_loss:
60.6831
Epoch 138/400
7/7 [==============================] - 0s 3ms/step - loss: 68.0797 - val_loss:
60.4708
Epoch 139/400
7/7 [==============================] - 0s 3ms/step - loss: 68.1585 - val_loss:
60.0813
Epoch 140/400
7/7 [==============================] - 0s 3ms/step - loss: 67.4914 - val_loss:
```

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59.6526
Epoch 141/400
7/7 [==============================] - 0s 3ms/step - loss: 67.1536 - val_loss:
59.1673
Epoch 142/400
7/7 [==============================] - 0s 3ms/step - loss: 66.9358 - val_loss:
60.0246
Epoch 143/400
7/7 [==============================] - 0s 3ms/step - loss: 66.4354 - val_loss:
58.6059
Epoch 144/400
7/7 [==============================] - 0s 3ms/step - loss: 65.9372 - val_loss:
58.7058
Epoch 145/400
7/7 [==============================] - 0s 3ms/step - loss: 65.1895 - val_loss:
59.0404
Epoch 146/400
7/7 [==============================] - 0s 3ms/step - loss: 65.1905 - val_loss:
57.9866
Epoch 147/400
7/7 [==============================] - 0s 3ms/step - loss: 64.8667 - val_loss:
58.0702
Epoch 148/400
7/7 [==============================] - 0s 3ms/step - loss: 63.9312 - val_loss:
57.9181
Epoch 149/400
7/7 [==============================] - 0s 3ms/step - loss: 63.6998 - val_loss:
57.5075
Epoch 150/400
7/7 [==============================] - 0s 3ms/step - loss: 63.3460 - val_loss:
57.3234
Epoch 151/400
7/7 [==============================] - 0s 3ms/step - loss: 62.6854 - val_loss:
56.5315
Epoch 152/400
7/7 [==============================] - 0s 3ms/step - loss: 62.5580 - val_loss:
56.6052
Epoch 153/400
7/7 [==============================] - 0s 3ms/step - loss: 62.1310 - val_loss:
55.9849
Epoch 154/400
7/7 [==============================] - 0s 3ms/step - loss: 61.4963 - val_loss:
55.4379
Epoch 155/400
7/7 [==============================] - 0s 3ms/step - loss: 61.3743 - val_loss:
55.8411
Epoch 156/400
7/7 [==============================] - 0s 3ms/step - loss: 61.2321 - val_loss:
```

```
54.8196
Epoch 157/400
7/7 [==============================] - 0s 3ms/step - loss: 61.2964 - val_loss:
56.8759
Epoch 158/400
7/7 [==============================] - 0s 3ms/step - loss: 61.2635 - val_loss:
53.9383
Epoch 159/400
7/7 [==============================] - 0s 3ms/step - loss: 60.0887 - val_loss:
54.3141
Epoch 160/400
7/7 [==============================] - 0s 3ms/step - loss: 59.4100 - val_loss:
53.2708
Epoch 161/400
7/7 [==============================] - 0s 3ms/step - loss: 60.1526 - val_loss:
54.9199
Epoch 162/400
7/7 [==============================] - 0s 3ms/step - loss: 59.4172 - val_loss:
52.9028
Epoch 163/400
7/7 [==============================] - 0s 3ms/step - loss: 58.4290 - val_loss:
53.2608
Epoch 164/400
7/7 [==============================] - 0s 3ms/step - loss: 58.2248 - val_loss:
52.1335
Epoch 165/400
7/7 [==============================] - 0s 2ms/step - loss: 57.6299 - val_loss:
51.9141
Epoch 166/400
7/7 [==============================] - 0s 3ms/step - loss: 57.2623 - val_loss:
51.6541
Epoch 167/400
7/7 [==============================] - 0s 3ms/step - loss: 57.2798 - val_loss:
51.7029
Epoch 168/400
7/7 [==============================] - 0s 3ms/step - loss: 56.8169 - val_loss:
51.6462
Epoch 169/400
7/7 [==============================] - 0s 3ms/step - loss: 56.1377 - val_loss:
51.1733
Epoch 170/400
7/7 [==============================] - 0s 3ms/step - loss: 55.4146 - val_loss:
50.6746
Epoch 171/400
7/7 [==============================] - 0s 3ms/step - loss: 55.1793 - val_loss:
51.4101
Epoch 172/400
7/7 [==============================] - 0s 3ms/step - loss: 55.2765 - val_loss:
```

```
50.4976
Epoch 173/400
7/7 [==============================] - 0s 3ms/step - loss: 54.8245 - val_loss:
50.0213
Epoch 174/400
7/7 [==============================] - 0s 3ms/step - loss: 54.9710 - val_loss:
50.6922
Epoch 175/400
7/7 [==============================] - 0s 3ms/step - loss: 53.9680 - val_loss:
49.3613
Epoch 176/400
7/7 [==============================] - 0s 3ms/step - loss: 53.5265 - val_loss:
50.0147
Epoch 177/400
7/7 [==============================] - 0s 3ms/step - loss: 53.1516 - val_loss:
49.8415
Epoch 178/400
7/7 [==============================] - 0s 3ms/step - loss: 53.5920 - val_loss:
48.9431
Epoch 179/400
7/7 [==============================] - 0s 3ms/step - loss: 53.1128 - val_loss:
51.2482
Epoch 180/400
7/7 [==============================] - 0s 3ms/step - loss: 53.6392 - val_loss:
48.3569
Epoch 181/400
7/7 [==============================] - 0s 3ms/step - loss: 51.7784 - val_loss:
49.2123
Epoch 182/400
7/7 [==============================] - 0s 3ms/step - loss: 51.7365 - val_loss:
49.0435
Epoch 183/400
7/7 [==============================] - 0s 3ms/step - loss: 51.4269 - val_loss:
48.5132
Epoch 184/400
7/7 [==============================] - 0s 2ms/step - loss: 51.8832 - val_loss:
47.6919
Epoch 185/400
7/7 [==============================] - 0s 3ms/step - loss: 50.7717 - val_loss:
48.7518
Epoch 186/400
7/7 [==============================] - 0s 3ms/step - loss: 50.3409 - val_loss:
47.4757
Epoch 187/400
7/7 [==============================] - 0s 3ms/step - loss: 50.4531 - val_loss:
48.6520
Epoch 188/400
7/7 [==============================] - 0s 3ms/step - loss: 50.0483 - val_loss:
```

```
47.2217
Epoch 189/400
7/7 [==============================] - 0s 2ms/step - loss: 49.8949 - val_loss:
48.4986
Epoch 190/400
7/7 [==============================] - ETA: 0s - loss: 42.16 - 0s 3ms/step -
loss: 50.1144 - val_loss: 47.1089
Epoch 191/400
7/7 [==============================] - 0s 3ms/step - loss: 49.7383 - val_loss:
48.7421
Epoch 192/400
7/7 [==============================] - 0s 3ms/step - loss: 49.3443 - val_loss:
47.2399
Epoch 193/400
7/7 [==============================] - 0s 3ms/step - loss: 48.9860 - val_loss:
47.7874
Epoch 194/400
7/7 [==============================] - 0s 2ms/step - loss: 48.8293 - val_loss:
47.4867
Epoch 195/400
7/7 [==============================] - 0s 3ms/step - loss: 48.5485 - val_loss:
47.3379
Epoch 196/400
7/7 [==============================] - 0s 3ms/step - loss: 48.5663 - val_loss:
47.0699
Epoch 197/400
7/7 [==============================] - 0s 3ms/step - loss: 48.4487 - val_loss:
47.7425
Epoch 198/400
7/7 [==============================] - 0s 3ms/step - loss: 48.9289 - val_loss:
46.3859
Epoch 199/400
7/7 [==============================] - 0s 3ms/step - loss: 48.0593 - val_loss:
47.3561
Epoch 200/400
7/7 [==============================] - 0s 3ms/step - loss: 47.9093 - val_loss:
46.6186
Epoch 201/400
7/7 [==============================] - 0s 3ms/step - loss: 48.1189 - val_loss:
46.8720
Epoch 202/400
7/7 [==============================] - 0s 3ms/step - loss: 47.8221 - val_loss:
46.9844
Epoch 203/400
7/7 [==============================] - 0s 3ms/step - loss: 47.3660 - val_loss:
46.3417
Epoch 204/400
7/7 [==============================] - 0s 3ms/step - loss: 47.3676 - val_loss:
```

```
46.3237
Epoch 205/400
7/7 [==============================] - 0s 3ms/step - loss: 47.1843 - val_loss:
46.3023
Epoch 206/400
7/7 [==============================] - 0s 3ms/step - loss: 47.0895 - val_loss:
46.6334
Epoch 207/400
7/7 [==============================] - 0s 3ms/step - loss: 47.3744 - val_loss:
45.8680
Epoch 208/400
7/7 [==============================] - 0s 3ms/step - loss: 47.2676 - val_loss:
46.5239
Epoch 209/400
7/7 [==============================] - 0s 3ms/step - loss: 47.2854 - val_loss:
47.5345
Epoch 210/400
7/7 [==============================] - 0s 3ms/step - loss: 46.9643 - val_loss:
45.4544
Epoch 211/400
7/7 [==============================] - 0s 3ms/step - loss: 46.2953 - val_loss:
49.3516
Epoch 212/400
7/7 [==============================] - 0s 3ms/step - loss: 47.2176 - val_loss:
46.0816
Epoch 213/400
7/7 [==============================] - 0s 3ms/step - loss: 47.2206 - val_loss:
48.5340
Epoch 214/400
7/7 [==============================] - 0s 3ms/step - loss: 46.8047 - val_loss:
45.8613
Epoch 215/400
7/7 [==============================] - 0s 3ms/step - loss: 46.2770 - val_loss:
45.4549
Epoch 216/400
7/7 [==============================] - 0s 3ms/step - loss: 46.7972 - val_loss:
48.2548
Epoch 217/400
7/7 [==============================] - 0s 3ms/step - loss: 46.7219 - val_loss:
45.4943
Epoch 218/400
7/7 [==============================] - 0s 3ms/step - loss: 46.0410 - val_loss:
46.0363
Epoch 219/400
7/7 [==============================] - 0s 3ms/step - loss: 46.0152 - val_loss:
47.0925
Epoch 220/400
7/7 [==============================] - 0s 3ms/step - loss: 45.8704 - val_loss:
```

```
45.0404
Epoch 221/400
7/7 [==============================] - 0s 3ms/step - loss: 46.0474 - val_loss:
46.3280
Epoch 222/400
7/7 [==============================] - 0s 3ms/step - loss: 45.2903 - val_loss:
46.1049
Epoch 223/400
7/7 [==============================] - 0s 3ms/step - loss: 45.2204 - val_loss:
45.3858
Epoch 224/400
7/7 [==============================] - 0s 3ms/step - loss: 45.4016 - val_loss:
47.8457
Epoch 225/400
7/7 [==============================] - 0s 3ms/step - loss: 45.4072 - val_loss:
45.2590
Epoch 226/400
7/7 [==============================] - 0s 3ms/step - loss: 44.8226 - val_loss:
48.2978
Epoch 227/400
7/7 [==============================] - 0s 3ms/step - loss: 45.4784 - val_loss:
44.8772
Epoch 228/400
7/7 [==============================] - 0s 3ms/step - loss: 44.6201 - val_loss:
48.0400
Epoch 229/400
7/7 [==============================] - 0s 3ms/step - loss: 45.2221 - val_loss:
44.7687
Epoch 230/400
7/7 [==============================] - 0s 3ms/step - loss: 45.0923 - val_loss:
46.7971
Epoch 231/400
7/7 [==============================] - 0s 3ms/step - loss: 44.6115 - val_loss:
44.8473
Epoch 232/400
7/7 [==============================] - 0s 3ms/step - loss: 44.2534 - val_loss:
46.7624
Epoch 233/400
7/7 [==============================] - 0s 3ms/step - loss: 44.2214 - val_loss:
44.5385
Epoch 234/400
7/7 [==============================] - 0s 3ms/step - loss: 44.3398 - val_loss:
47.0116
Epoch 235/400
7/7 [==============================] - 0s 3ms/step - loss: 44.5644 - val_loss:
44.6429
Epoch 236/400
7/7 [==============================] - 0s 3ms/step - loss: 44.5048 - val_loss:
```

```
45.7402
Epoch 237/400
7/7 [==============================] - 0s 3ms/step - loss: 44.2793 - val_loss:
44.8927
Epoch 238/400
7/7 [==============================] - 0s 3ms/step - loss: 44.0415 - val_loss:
45.0137
Epoch 239/400
7/7 [==============================] - 0s 3ms/step - loss: 44.1350 - val_loss:
45.4418
Epoch 240/400
7/7 [==============================] - 0s 3ms/step - loss: 44.5168 - val_loss:
47.2283
Epoch 241/400
7/7 [==============================] - 0s 3ms/step - loss: 44.5846 - val_loss:
44.5021
Epoch 242/400
7/7 [==============================] - 0s 3ms/step - loss: 44.8538 - val_loss:
46.7107
Epoch 243/400
7/7 [==============================] - 0s 3ms/step - loss: 43.9508 - val_loss:
44.4866
Epoch 244/400
7/7 [==============================] - 0s 3ms/step - loss: 43.5043 - val_loss:
45.8101
Epoch 245/400
7/7 [==============================] - 0s 3ms/step - loss: 44.0890 - val_loss:
45.8260
Epoch 246/400
7/7 [==============================] - 0s 3ms/step - loss: 43.9352 - val_loss:
44.3676
Epoch 247/400
7/7 [==============================] - 0s 3ms/step - loss: 44.3785 - val_loss:
47.4438
Epoch 248/400
7/7 [==============================] - 0s 3ms/step - loss: 43.9401 - val_loss:
44.5632
Epoch 249/400
7/7 [==============================] - 0s 3ms/step - loss: 45.1829 - val_loss:
47.5237
Epoch 250/400
7/7 [==============================] - 0s 3ms/step - loss: 44.3410 - val_loss:
45.1721
Epoch 251/400
7/7 [==============================] - 0s 3ms/step - loss: 43.9320 - val_loss:
45.2212
Epoch 252/400
7/7 [==============================] - 0s 3ms/step - loss: 43.6464 - val_loss:
```

44.0301
Epoch 253/400
7/7 [==============================] - 0s 3ms/step - loss: 43.8036 - val_loss: 44.4261
Epoch 254/400
7/7 [==============================] - 0s 3ms/step - loss: 43.6578 - val_loss: 44.2183
Epoch 255/400
7/7 [==============================] - 0s 3ms/step - loss: 43.2309 - val_loss: 46.8413
Epoch 256/400
7/7 [==============================] - 0s 3ms/step - loss: 43.5268 - val_loss: 44.4353
Epoch 257/400
7/7 [==============================] - 0s 3ms/step - loss: 43.1496 - val_loss: 45.9353
Epoch 258/400
7/7 [==============================] - 0s 3ms/step - loss: 43.3594 - val_loss: 44.1830
Epoch 259/400
7/7 [==============================] - 0s 3ms/step - loss: 43.3043 - val_loss: 49.0198
Epoch 260/400
7/7 [==============================] - 0s 3ms/step - loss: 44.1971 - val_loss: 44.3749
Epoch 261/400
7/7 [==============================] - 0s 3ms/step - loss: 43.1867 - val_loss: 49.5640
Epoch 262/400
7/7 [==============================] - 0s 3ms/step - loss: 43.8257 - val_loss: 44.5551
Epoch 263/400
7/7 [==============================] - 0s 3ms/step - loss: 44.0289 - val_loss: 46.5772
Epoch 264/400
7/7 [==============================] - 0s 3ms/step - loss: 43.0324 - val_loss: 44.0145
Epoch 265/400
7/7 [==============================] - 0s 3ms/step - loss: 43.3099 - val_loss: 44.4700
Epoch 266/400
7/7 [==============================] - 0s 3ms/step - loss: 42.7710 - val_loss: 44.4905
Epoch 267/400
7/7 [==============================] - 0s 3ms/step - loss: 42.6843 - val_loss: 44.9180
Epoch 268/400
7/7 [==============================] - 0s 3ms/step - loss: 42.7268 - val_loss:

```
44.8002
Epoch 269/400
7/7 [==============================] - 0s 3ms/step - loss: 42.6213 - val_loss:
45.2533
Epoch 270/400
7/7 [==============================] - 0s 3ms/step - loss: 43.3129 - val_loss:
43.9054
Epoch 271/400
7/7 [==============================] - 0s 3ms/step - loss: 44.3199 - val_loss:
45.5893
Epoch 272/400
7/7 [==============================] - 0s 3ms/step - loss: 43.0153 - val_loss:
44.0076
Epoch 273/400
7/7 [==============================] - 0s 3ms/step - loss: 43.3667 - val_loss:
43.7751
Epoch 274/400
7/7 [==============================] - 0s 3ms/step - loss: 42.8244 - val_loss:
45.2819
Epoch 275/400
7/7 [==============================] - 0s 3ms/step - loss: 42.8406 - val_loss:
43.8690
Epoch 276/400
7/7 [==============================] - 0s 3ms/step - loss: 42.4070 - val_loss:
45.1805
Epoch 277/400
7/7 [==============================] - 0s 3ms/step - loss: 42.6512 - val_loss:
45.0542
Epoch 278/400
7/7 [==============================] - 0s 3ms/step - loss: 42.5243 - val_loss:
44.4262
Epoch 279/400
7/7 [==============================] - 0s 3ms/step - loss: 42.2790 - val_loss:
44.5195
Epoch 280/400
7/7 [==============================] - 0s 3ms/step - loss: 42.5009 - val_loss:
44.9827
Epoch 281/400
7/7 [==============================] - 0s 3ms/step - loss: 42.3011 - val_loss:
44.1199
Epoch 282/400
7/7 [==============================] - 0s 3ms/step - loss: 42.4251 - val_loss:
44.7838
Epoch 283/400
7/7 [==============================] - 0s 3ms/step - loss: 42.0743 - val_loss:
44.0997
Epoch 284/400
7/7 [==============================] - 0s 3ms/step - loss: 42.3784 - val_loss:
```

```
44.4429
Epoch 285/400
7/7 [==============================] - 0s 3ms/step - loss: 42.2254 - val_loss:
44.1800
Epoch 286/400
7/7 [==============================] - 0s 3ms/step - loss: 42.3657 - val_loss:
43.5746
Epoch 287/400
7/7 [==============================] - 0s 3ms/step - loss: 42.2990 - val_loss:
44.9791
Epoch 288/400
7/7 [==============================] - 0s 3ms/step - loss: 42.4245 - val_loss:
43.9570
Epoch 289/400
7/7 [==============================] - 0s 3ms/step - loss: 43.2991 - val_loss:
50.7917
Epoch 290/400
7/7 [==============================] - 0s 3ms/step - loss: 44.0053 - val_loss:
43.4779
Epoch 291/400
7/7 [==============================] - 0s 3ms/step - loss: 42.2928 - val_loss:
43.7405
Epoch 292/400
7/7 [==============================] - 0s 3ms/step - loss: 42.3323 - val_loss:
44.5014
Epoch 293/400
7/7 [==============================] - 0s 3ms/step - loss: 41.8273 - val_loss:
43.5162
Epoch 294/400
7/7 [==============================] - 0s 3ms/step - loss: 42.1105 - val_loss:
43.7064
Epoch 295/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6711 - val_loss:
44.5826
Epoch 296/400
7/7 [==============================] - 0s 3ms/step - loss: 41.8391 - val_loss:
42.6400
Epoch 297/400
7/7 [==============================] - 0s 3ms/step - loss: 42.0839 - val_loss:
43.9823
Epoch 298/400
7/7 [==============================] - 0s 3ms/step - loss: 41.5820 - val_loss:
42.8088
Epoch 299/400
7/7 [==============================] - 0s 3ms/step - loss: 42.1182 - val_loss:
44.5335
Epoch 300/400
7/7 [==============================] - 0s 3ms/step - loss: 41.5866 - val_loss:
```

```
43.2071
Epoch 301/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6787 - val_loss:
44.1535
Epoch 302/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6835 - val_loss:
44.0678
Epoch 303/400
7/7 [==============================] - 0s 3ms/step - loss: 41.4453 - val_loss:
44.0236
Epoch 304/400
7/7 [==============================] - 0s 3ms/step - loss: 41.5069 - val_loss:
43.5975
Epoch 305/400
7/7 [==============================] - 0s 3ms/step - loss: 41.9047 - val_loss:
44.8474
Epoch 306/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6086 - val_loss:
43.1534
Epoch 307/400
7/7 [==============================] - 0s 3ms/step - loss: 41.5303 - val_loss:
42.7298
Epoch 308/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6158 - val_loss:
45.9504
Epoch 309/400
7/7 [==============================] - 0s 3ms/step - loss: 43.0861 - val_loss:
42.7341
Epoch 310/400
7/7 [==============================] - 0s 3ms/step - loss: 41.8819 - val_loss:
44.6117
Epoch 311/400
7/7 [==============================] - 0s 3ms/step - loss: 41.9326 - val_loss:
43.7957
Epoch 312/400
7/7 [==============================] - 0s 3ms/step - loss: 42.0897 - val_loss:
42.8131
Epoch 313/400
7/7 [==============================] - 0s 3ms/step - loss: 41.2432 - val_loss:
42.9411
Epoch 314/400
7/7 [==============================] - 0s 3ms/step - loss: 41.2538 - val_loss:
43.0138
Epoch 315/400
7/7 [==============================] - 0s 3ms/step - loss: 41.0212 - val_loss:
43.7077
Epoch 316/400
7/7 [==============================] - 0s 3ms/step - loss: 41.4065 - val_loss:
```

```
42.4518
Epoch 317/400
7/7 [==============================] - 0s 3ms/step - loss: 41.5391 - val_loss:
44.1773
Epoch 318/400
7/7 [==============================] - 0s 3ms/step - loss: 41.0864 - val_loss:
42.5356
Epoch 319/400
7/7 [==============================] - 0s 3ms/step - loss: 40.9397 - val_loss:
42.9135
Epoch 320/400
7/7 [==============================] - 0s 3ms/step - loss: 40.9861 - val_loss:
44.1604
Epoch 321/400
7/7 [==============================] - 0s 3ms/step - loss: 41.0687 - val_loss:
42.5750
Epoch 322/400
7/7 [==============================] - 0s 3ms/step - loss: 40.9218 - val_loss:
43.3573
Epoch 323/400
7/7 [==============================] - 0s 3ms/step - loss: 40.8294 - val_loss:
42.2866
Epoch 324/400
7/7 [==============================] - 0s 3ms/step - loss: 41.1817 - val_loss:
42.9576
Epoch 325/400
7/7 [==============================] - 0s 3ms/step - loss: 41.1383 - val_loss:
46.4091
Epoch 326/400
7/7 [==============================] - 0s 3ms/step - loss: 42.2011 - val_loss:
42.5587
Epoch 327/400
7/7 [==============================] - 0s 3ms/step - loss: 41.8918 - val_loss:
44.3349
Epoch 328/400
7/7 [==============================] - 0s 3ms/step - loss: 41.3114 - val_loss:
43.2276
Epoch 329/400
7/7 [==============================] - 0s 3ms/step - loss: 41.4056 - val_loss:
41.8275
Epoch 330/400
7/7 [==============================] - 0s 3ms/step - loss: 41.8444 - val_loss:
46.5434
Epoch 331/400
7/7 [==============================] - 0s 3ms/step - loss: 41.3687 - val_loss:
41.9355
Epoch 332/400
7/7 [==============================] - 0s 3ms/step - loss: 40.9197 - val_loss:
```

42.6079
Epoch 333/400
7/7 [==============================] - 0s 3ms/step - loss: 40.7374 - val_loss:
44.5767
Epoch 334/400
7/7 [==============================] - 0s 3ms/step - loss: 41.6003 - val_loss:
41.7780
Epoch 335/400
7/7 [==============================] - 0s 3ms/step - loss: 40.7912 - val_loss:
42.6180
Epoch 336/400
7/7 [==============================] - 0s 3ms/step - loss: 40.6971 - val_loss:
44.3947
Epoch 337/400
7/7 [==============================] - 0s 3ms/step - loss: 41.1064 - val_loss:
41.7205
Epoch 338/400
7/7 [==============================] - 0s 3ms/step - loss: 39.9928 - val_loss:
46.5346
Epoch 339/400
7/7 [==============================] - 0s 3ms/step - loss: 42.6630 - val_loss:
42.1233
Epoch 340/400
7/7 [==============================] - 0s 3ms/step - loss: 41.3406 - val_loss:
43.6290
Epoch 341/400
7/7 [==============================] - 0s 3ms/step - loss: 41.0695 - val_loss:
43.0989
Epoch 342/400
7/7 [==============================] - 0s 2ms/step - loss: 40.3624 - val_loss:
42.1824
Epoch 343/400
7/7 [==============================] - 0s 3ms/step - loss: 39.9836 - val_loss:
42.1762
Epoch 344/400
7/7 [==============================] - 0s 3ms/step - loss: 40.0567 - val_loss:
41.6763
Epoch 345/400
7/7 [==============================] - 0s 3ms/step - loss: 40.1075 - val_loss:
41.8872
Epoch 346/400
7/7 [==============================] - 0s 3ms/step - loss: 39.9309 - val_loss:
41.3554
Epoch 347/400
7/7 [==============================] - 0s 3ms/step - loss: 39.9410 - val_loss:
41.9624
Epoch 348/400
7/7 [==============================] - 0s 3ms/step - loss: 39.7483 - val_loss:

```
41.5849
Epoch 349/400
7/7 [==============================] - 0s 3ms/step - loss: 40.0979 - val_loss:
41.0906
Epoch 350/400
7/7 [==============================] - 0s 3ms/step - loss: 39.8580 - val_loss:
41.5787
Epoch 351/400
7/7 [==============================] - 0s 3ms/step - loss: 40.0458 - val_loss:
41.3447
Epoch 352/400
7/7 [==============================] - 0s 3ms/step - loss: 40.1477 - val_loss:
43.3074
Epoch 353/400
7/7 [==============================] - 0s 3ms/step - loss: 39.8161 - val_loss:
41.0987
Epoch 354/400
7/7 [==============================] - 0s 3ms/step - loss: 39.3502 - val_loss:
42.4865
Epoch 355/400
7/7 [==============================] - 0s 3ms/step - loss: 39.6293 - val_loss:
41.0014
Epoch 356/400
7/7 [==============================] - 0s 3ms/step - loss: 39.3482 - val_loss:
42.1550
Epoch 357/400
7/7 [==============================] - 0s 3ms/step - loss: 39.4105 - val_loss:
41.8452
Epoch 358/400
7/7 [==============================] - 0s 3ms/step - loss: 39.4427 - val_loss:
41.1494
Epoch 359/400
7/7 [==============================] - 0s 3ms/step - loss: 39.3806 - val_loss:
41.2416
Epoch 360/400
7/7 [==============================] - 0s 3ms/step - loss: 39.0588 - val_loss:
41.8345
Epoch 361/400
7/7 [==============================] - 0s 3ms/step - loss: 38.9573 - val_loss:
40.2576
Epoch 362/400
7/7 [==============================] - 0s 3ms/step - loss: 39.8652 - val_loss:
40.7502
Epoch 363/400
7/7 [==============================] - 0s 3ms/step - loss: 39.5397 - val_loss:
41.4834
Epoch 364/400
7/7 [==============================] - 0s 3ms/step - loss: 38.9700 - val_loss:
```

```
42.8860
Epoch 365/400
7/7 [==============================] - 0s 3ms/step - loss: 39.8039 - val_loss:
40.1426
Epoch 366/400
7/7 [==============================] - 0s 3ms/step - loss: 39.0672 - val_loss:
45.3333
Epoch 367/400
7/7 [==============================] - 0s 3ms/step - loss: 39.3620 - val_loss:
40.4457
Epoch 368/400
7/7 [==============================] - 0s 3ms/step - loss: 40.2835 - val_loss:
43.1630
Epoch 369/400
7/7 [==============================] - 0s 3ms/step - loss: 38.1976 - val_loss:
39.8676
Epoch 370/400
7/7 [==============================] - 0s 3ms/step - loss: 39.0254 - val_loss:
40.8587
Epoch 371/400
7/7 [==============================] - 0s 3ms/step - loss: 38.7802 - val_loss:
42.6925
Epoch 372/400
7/7 [==============================] - 0s 3ms/step - loss: 38.6648 - val_loss:
39.8806
Epoch 373/400
7/7 [==============================] - 0s 3ms/step - loss: 40.0581 - val_loss:
42.2835
Epoch 374/400
7/7 [==============================] - 0s 3ms/step - loss: 38.1601 - val_loss:
39.6683
Epoch 375/400
7/7 [==============================] - 0s 3ms/step - loss: 38.8507 - val_loss:
40.8396
Epoch 376/400
7/7 [==============================] - 0s 3ms/step - loss: 38.9915 - val_loss:
43.8077
Epoch 377/400
7/7 [==============================] - 0s 3ms/step - loss: 39.0997 - val_loss:
40.4930
Epoch 378/400
7/7 [==============================] - 0s 3ms/step - loss: 38.2400 - val_loss:
40.4233
Epoch 379/400
7/7 [==============================] - 0s 3ms/step - loss: 38.1627 - val_loss:
41.7753
Epoch 380/400
7/7 [==============================] - 0s 3ms/step - loss: 38.0545 - val_loss:
```

```
39.6325
Epoch 381/400
7/7 [==============================] - 0s 3ms/step - loss: 37.9521 - val_loss:
43.0120
Epoch 382/400
7/7 [==============================] - 0s 3ms/step - loss: 38.2423 - val_loss:
39.9728
Epoch 383/400
7/7 [==============================] - 0s 3ms/step - loss: 37.9971 - val_loss:
40.2657
Epoch 384/400
7/7 [==============================] - 0s 3ms/step - loss: 38.1160 - val_loss:
41.3274
Epoch 385/400
7/7 [==============================] - 0s 3ms/step - loss: 37.8311 - val_loss:
40.3087
Epoch 386/400
7/7 [==============================] - 0s 3ms/step - loss: 37.8622 - val_loss:
42.6194
Epoch 387/400
7/7 [==============================] - 0s 3ms/step - loss: 38.4573 - val_loss:
40.3869
Epoch 388/400
7/7 [==============================] - 0s 3ms/step - loss: 37.9009 - val_loss:
39.5894
Epoch 389/400
7/7 [==============================] - 0s 3ms/step - loss: 38.1472 - val_loss:
44.1040
Epoch 390/400
7/7 [==============================] - 0s 3ms/step - loss: 39.1676 - val_loss:
39.5866
Epoch 391/400
7/7 [==============================] - 0s 3ms/step - loss: 37.6550 - val_loss:
41.0239
Epoch 392/400
7/7 [==============================] - 0s 3ms/step - loss: 37.6419 - val_loss:
39.3443
Epoch 393/400
7/7 [==============================] - 0s 3ms/step - loss: 37.7259 - val_loss:
40.8900
Epoch 394/400
7/7 [==============================] - 0s 3ms/step - loss: 37.4189 - val_loss:
39.6160
Epoch 395/400
7/7 [==============================] - 0s 3ms/step - loss: 37.5468 - val_loss:
40.6460
Epoch 396/400
7/7 [==============================] - 0s 3ms/step - loss: 37.3967 - val_loss:
```

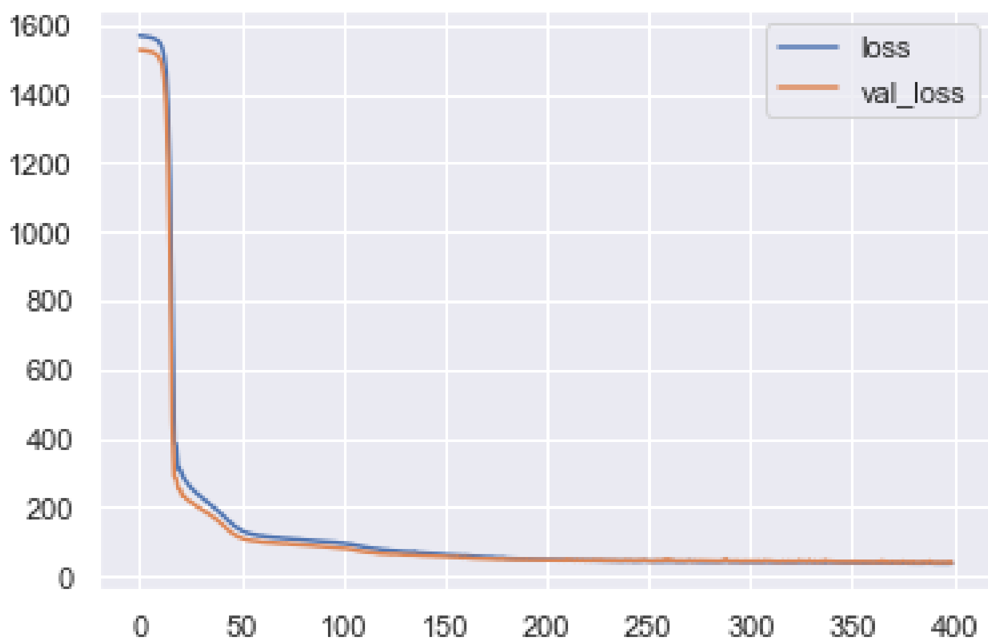
```
40.8379
Epoch 397/400
7/7 [==============================] - 0s 3ms/step - loss: 37.4234 - val_loss:
40.6853
Epoch 398/400
7/7 [==============================] - 0s 3ms/step - loss: 37.2790 - val_loss:
39.7271
Epoch 399/400
7/7 [==============================] - 0s 3ms/step - loss: 37.4510 - val_loss:
42.8591
Epoch 400/400
7/7 [==============================] - 0s 3ms/step - loss: 38.4220 - val_loss:
39.1298
```

[53]: <tensorflow.python.keras.callbacks.History at 0x7fe7458b6cd0>

1.7.3 Visualize the Loss Function

[54]:
```
losses = pd.DataFrame(model_4.history.history)
losses.plot()
```

[54]: <matplotlib.axes._subplots.AxesSubplot at 0x7fe7458c7100>



1.7.4 Test the Model

[55]:
```
predictions_4 = model_4.predict(X_test)
```

1.7.5 Model Evaluation

[57]:
```
# Model Evaluation Metrics
MAE_4 = mean_absolute_error(y_test,predictions_4)
RMSE_4 = np.sqrt(mean_squared_error(y_test,predictions_4))
EVS_4 = explained_variance_score(y_test,predictions_4)

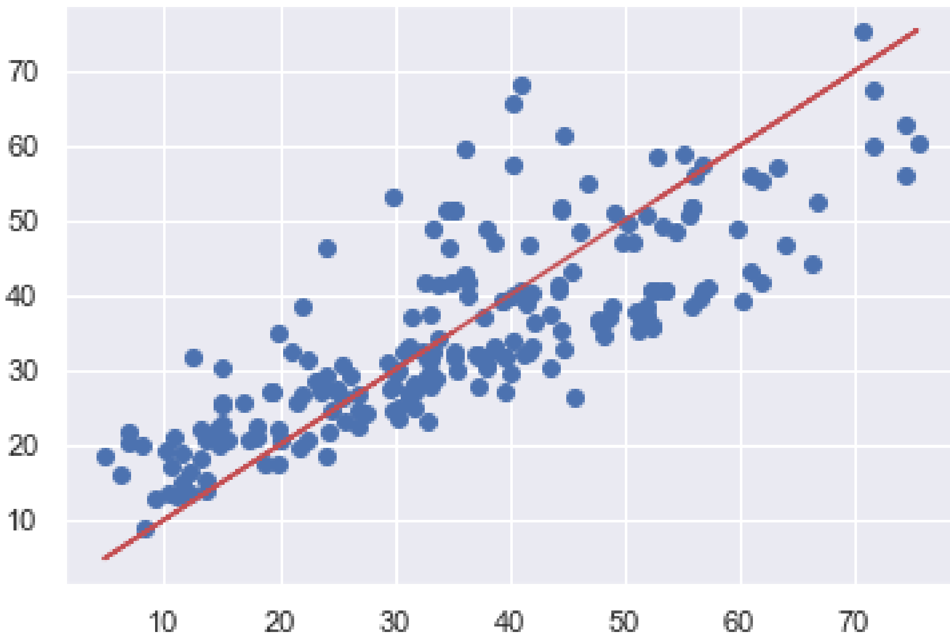
print('EVALUATION METRICS')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_4}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE_4}\nExplained Variance Score:\t\t{EVS_4}")
```

```
EVALUATION METRICS
-----------------------------
Mean Absolute Error (MAE):             4.913074249712009
Root Mean Squared Error (RMSE):        6.255377818962742
Explained Variance Score:              0.8488666652349717
```

[58]:
```
# Plot Model Predictions (Scatter)
plt.scatter(y_test,predictions_3)

# Plot Perfect predictions (Line)
plt.plot(y_test,y_test,'r')
```

[58]:
```
[<matplotlib.lines.Line2D at 0x7fe7422f7ca0>]
```



1.7.6 Model Comparison

Let us compare the evaluation metrics between models 1, 2, 3, and 4:

[75]:
```
print('EVALUATION METRICS, MODEL 1')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE}\nExplained Variance Score:\t\t{EVS}")
print('-----------------------------\n\n')
print('EVALUATION METRICS, MODEL 2')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_2}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE_2}\nExplained Variance Score:\t\t{EVS_2}")
print('-----------------------------\n\n')
print('EVALUATION METRICS, MODEL 3')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_3}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE_3}\nExplained Variance Score:\t\t{EVS_3}")
print('-----------------------------\n\n')
print('EVALUATION METRICS, MODEL 4')
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_4}\nRoot Mean Squared Error (RMSE):
↪\t\t{RMSE_4}\nExplained Variance Score:\t\t{EVS_4}")
```

```
EVALUATION METRICS, MODEL 1
-----------------------------
```

```
Mean Absolute Error (MAE):            7.23883411296363
Root Mean Squared Error (RMSE):       9.233359748913385
Explained Variance Score:             0.6691982422589368
-----------------------------


EVALUATION METRICS, MODEL 2
-----------------------------
Mean Absolute Error (MAE):            5.738010522323906
Root Mean Squared Error (RMSE):       7.266889552774522
Explained Variance Score:             0.797885663610966
-----------------------------


EVALUATION METRICS, MODEL 3
-----------------------------
Mean Absolute Error (MAE):            7.611444954733247
Root Mean Squared Error (RMSE):       9.619967686192227
Explained Variance Score:             0.6426482928244076
-----------------------------


EVALUATION METRICS, MODEL 4
-----------------------------
Mean Absolute Error (MAE):            4.913074249712009
Root Mean Squared Error (RMSE):       6.255377818962742
Explained Variance Score:             0.8488666652349717
```

1.8 Determining Optimal Number of Hidden Layers

1.8.1 Iterating Through 2-50 Hidden Layers

We now know that 15 hidden layers is more effective than 20. Let us iterate from 2 to 50 to explore the other possible number of layers, assuming each deep layer contains 8 nodes. Once we find the optimal number of nodes in that range, we can further experiment to optimize the ANN architecture. The for loop below will print out the evaluation metrics for each iteration in real time. Please note that it may take several minutes to run the following code.

[138]:
```python
results = []
for i in range(2,51):
    model_loop = Sequential()
    for j in range(0,(i+1)):
        model_loop.add(Dense(8,activation='relu'))
    model_loop.add(Dense(1))

    model_loop.compile(optimizer='adam',loss='mse')

    # We will reduce epochs to 200 to reduce run time.
```

```
    # 200 was chosen based on previous loss function visualizations.
    model_loop.fit(x=X_train,y=y_train.values,
          validation_data=(X_test,y_test.values),
          batch_size=128,epochs=200,verbose=0)

    # Model evaluation
    predictions_loop = model_loop.predict(X_test)

    MAE_loop = mean_absolute_error(y_test,predictions_loop)
    RMSE_loop = np.sqrt(mean_squared_error(y_test,predictions_loop))
    EVS_loop = explained_variance_score(y_test,predictions_loop)

    results.append([i, MAE_loop,RMSE_loop,EVS_loop])

    print(f"EVALUATION METRICS, HIDDEN LAYERS = {i}")
    print('-----------------------------')
    print(f"Mean Absolute Error (MAE):\t\t{MAE_loop}\nRoot Mean Squared Error␣
↪(RMSE):\t\t{RMSE_loop}\nExplained Variance Score:\t\t{EVS_loop}")
    print('-----------------------------\n\n')
```

```
EVALUATION METRICS, HIDDEN LAYERS = 2
-----------------------------
Mean Absolute Error (MAE):              8.120154531719615
Root Mean Squared Error (RMSE):         10.110879538827527
Explained Variance Score:               0.603573240618023
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 3
-----------------------------
Mean Absolute Error (MAE):              6.316067462847071
Root Mean Squared Error (RMSE):         8.01847651997628
Explained Variance Score:               0.7504890012616049
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 4
-----------------------------
Mean Absolute Error (MAE):              6.733620031967904
Root Mean Squared Error (RMSE):         8.728310582799304
Explained Variance Score:               0.7044559113122469
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 5
-----------------------------
Mean Absolute Error (MAE):              5.57671700866477
```

```
Root Mean Squared Error (RMSE):        6.996037765940304
Explained Variance Score:              0.8191998499945969
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 6
-----------------------------
Mean Absolute Error (MAE):             6.711770730250091
Root Mean Squared Error (RMSE):        8.615350695520469
Explained Variance Score:              0.7119503067668893
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 7
-----------------------------
Mean Absolute Error (MAE):             5.984079652064056
Root Mean Squared Error (RMSE):        7.614730395172845
Explained Variance Score:              0.7755222006242926
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 8
-----------------------------
Mean Absolute Error (MAE):             5.735270093158611
Root Mean Squared Error (RMSE):        7.086722805080626
Explained Variance Score:              0.8053037696318728
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 9
-----------------------------
Mean Absolute Error (MAE):             5.478865822542061
Root Mean Squared Error (RMSE):        6.867825825775559
Explained Variance Score:              0.819553935582044
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 10
-----------------------------
Mean Absolute Error (MAE):             7.823388269294812
Root Mean Squared Error (RMSE):        9.795787697246654
Explained Variance Score:              0.6284665360679961
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 11
-----------------------------
Mean Absolute Error (MAE):             5.583180159041025
```

```
Root Mean Squared Error (RMSE):        6.984229234247302
Explained Variance Score:              0.8208125412740914
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 12
-----------------------------
Mean Absolute Error (MAE):             5.378429776812063
Root Mean Squared Error (RMSE):        6.801692005893954
Explained Variance Score:              0.8254431803201379
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 13
-----------------------------
Mean Absolute Error (MAE):             6.112327872248529
Root Mean Squared Error (RMSE):        7.62031079259648
Explained Variance Score:              0.7747771892371211
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 14
-----------------------------
Mean Absolute Error (MAE):             5.5185722788097795
Root Mean Squared Error (RMSE):        6.858810612151086
Explained Variance Score:              0.8183444896012475
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 15
-----------------------------
Mean Absolute Error (MAE):             5.938035524886789
Root Mean Squared Error (RMSE):        7.459843610366862
Explained Variance Score:              0.7858784431548431
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 16
-----------------------------
Mean Absolute Error (MAE):             6.821452794676844
Root Mean Squared Error (RMSE):        8.900650789849243
Explained Variance Score:              0.6936457735710044
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 17
-----------------------------
Mean Absolute Error (MAE):             5.533272227500248
```

```
Root Mean Squared Error (RMSE):        6.793224274989845
Explained Variance Score:              0.8209112610561281
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 18
-----------------------------
Mean Absolute Error (MAE):             5.663948101302954
Root Mean Squared Error (RMSE):        7.359722788575843
Explained Variance Score:              0.8015666267805353
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 19
-----------------------------
Mean Absolute Error (MAE):             7.126552193095383
Root Mean Squared Error (RMSE):        9.161850954927273
Explained Variance Score:              0.6752519590130766
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 20
-----------------------------
Mean Absolute Error (MAE):             5.533255350612902
Root Mean Squared Error (RMSE):        7.090032891571433
Explained Variance Score:              0.8052541645002692
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 21
-----------------------------
Mean Absolute Error (MAE):             6.057331670001872
Root Mean Squared Error (RMSE):        7.735291412130756
Explained Variance Score:              0.7771645158797513
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 22
-----------------------------
Mean Absolute Error (MAE):             13.053801832476866
Root Mean Squared Error (RMSE):        16.054067583075092
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 23
-----------------------------
Mean Absolute Error (MAE):             13.063179582021768
```

```
Root Mean Squared Error (RMSE):        16.141319898403207
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 24
-----------------------------
Mean Absolute Error (MAE):             6.0291853160302615
Root Mean Squared Error (RMSE):        7.523479760077879
Explained Variance Score:              0.7818280460200446
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 25
-----------------------------
Mean Absolute Error (MAE):             5.45227837257015
Root Mean Squared Error (RMSE):        6.848838990375106
Explained Variance Score:              0.8230922728390744
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 26
-----------------------------
Mean Absolute Error (MAE):             13.04146576816596
Root Mean Squared Error (RMSE):        16.05251979248055
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 27
-----------------------------
Mean Absolute Error (MAE):             5.105980217294786
Root Mean Squared Error (RMSE):        6.488557487152753
Explained Variance Score:              0.8366699650916528
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 28
-----------------------------
Mean Absolute Error (MAE):             5.71979399412581
Root Mean Squared Error (RMSE):        7.53736009502298
Explained Variance Score:              0.7796426678238857
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 29
-----------------------------
Mean Absolute Error (MAE):             5.488801206570227
```

```
Root Mean Squared Error (RMSE):        6.935423136007702
Explained Variance Score:              0.8177958145966675
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 30
-----------------------------
Mean Absolute Error (MAE):             5.059363350451572
Root Mean Squared Error (RMSE):        6.513469468892874
Explained Variance Score:              0.8402378858490599
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 31
-----------------------------
Mean Absolute Error (MAE):             7.2751414971212744
Root Mean Squared Error (RMSE):        9.238453187252782
Explained Variance Score:              0.6689495050997574
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 32
-----------------------------
Mean Absolute Error (MAE):             13.047311662099894
Root Mean Squared Error (RMSE):        16.05246971586041
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 33
-----------------------------
Mean Absolute Error (MAE):             34.27170157488111
Root Mean Squared Error (RMSE):        37.844767448102836
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 34
-----------------------------
Mean Absolute Error (MAE):             13.059186999867263
Root Mean Squared Error (RMSE):        16.05671375701027
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 35
-----------------------------
Mean Absolute Error (MAE):             5.1497897412938975
```

```
Root Mean Squared Error (RMSE):        6.419044845657203
Explained Variance Score:              0.8438115650510409
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 36
-----------------------------
Mean Absolute Error (MAE):             13.034295915029581
Root Mean Squared Error (RMSE):        16.054508710066703
Explained Variance Score:              -2.5621756938321028e-08
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 37
-----------------------------
Mean Absolute Error (MAE):             13.054120193037015
Root Mean Squared Error (RMSE):        16.0541907207132
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 38
-----------------------------
Mean Absolute Error (MAE):             34.27141976412061
Root Mean Squared Error (RMSE):        37.844512244337785
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 39
-----------------------------
Mean Absolute Error (MAE):             5.128188093240979
Root Mean Squared Error (RMSE):        6.508868622553171
Explained Variance Score:              0.8360870774081537
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 40
-----------------------------
Mean Absolute Error (MAE):             5.668614755463832
Root Mean Squared Error (RMSE):        7.202048651134695
Explained Variance Score:              0.8214597430602204
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 41
-----------------------------
Mean Absolute Error (MAE):             13.052142031771465
```

```
Root Mean Squared Error (RMSE):        16.053493385733766
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 42
-----------------------------
Mean Absolute Error (MAE):             6.285670373231463
Root Mean Squared Error (RMSE):        7.894684085869782
Explained Variance Score:              0.758491275678627
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 43
-----------------------------
Mean Absolute Error (MAE):             4.913707746672399
Root Mean Squared Error (RMSE):        6.690457709869514
Explained Variance Score:              0.8339618633118577
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 44
-----------------------------
Mean Absolute Error (MAE):             4.953942543418663
Root Mean Squared Error (RMSE):        6.234954243834083
Explained Variance Score:              0.850606045042105
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 45
-----------------------------
Mean Absolute Error (MAE):             4.879614045226458
Root Mean Squared Error (RMSE):        6.422680429911674
Explained Variance Score:              0.8417760419622913
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 46
-----------------------------
Mean Absolute Error (MAE):             34.27101039942029
Root Mean Squared Error (RMSE):        37.8441415302349
Explained Variance Score:              0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 47
-----------------------------
Mean Absolute Error (MAE):             13.048629991846177
```

```
Root Mean Squared Error (RMSE):         16.05265348522672
Explained Variance Score:               0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 48
-----------------------------
Mean Absolute Error (MAE):              34.270735979635745
Root Mean Squared Error (RMSE):         37.84389302052811
Explained Variance Score:               0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 49
-----------------------------
Mean Absolute Error (MAE):              13.055442670803625
Root Mean Squared Error (RMSE):         16.054747037532167
Explained Variance Score:               0.0
-----------------------------


EVALUATION METRICS, HIDDEN LAYERS = 50
-----------------------------
Mean Absolute Error (MAE):              5.8415424287666395
Root Mean Squared Error (RMSE):         7.226975235195714
Explained Variance Score:               0.7981404573686495
-----------------------------
```

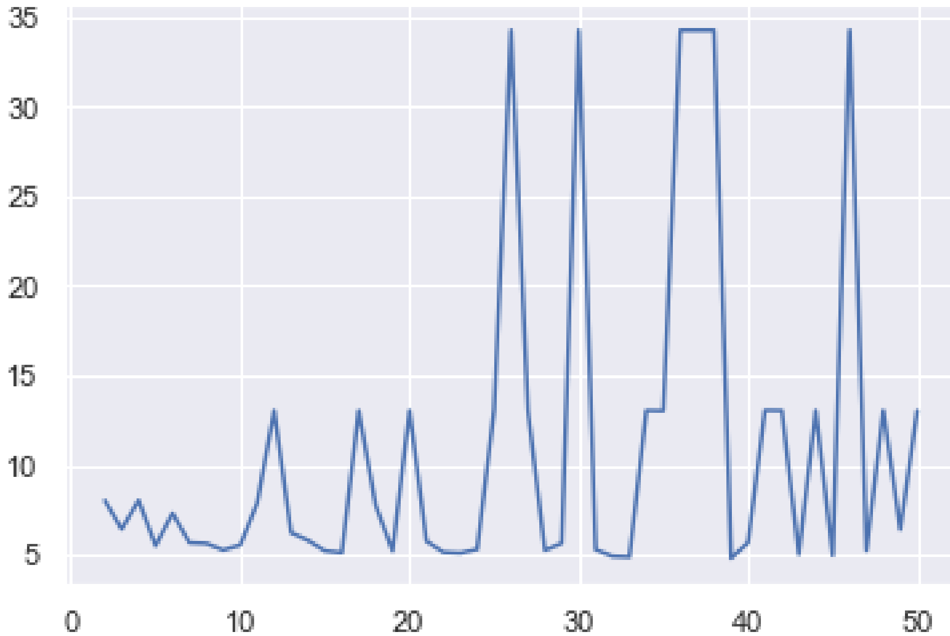
1.8.2 Layer Optimization Analysis

[144]:
```
# Convert the results into a numpy array
results_np = np.array(results)

# Store the np array in a pandas dataframe
results_df = pd.
 ↪DataFrame(columns=['Hidden_Layers','MAE','RMSE','EVS'],data=results_np)
```

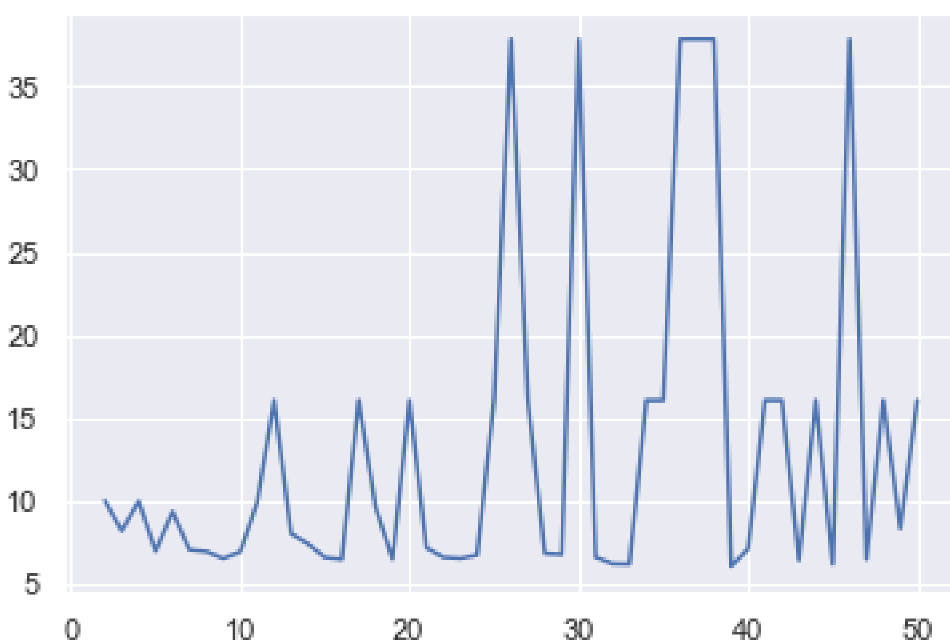
[114]:
```
# Plot the mean absolute error for each iteration
X_plot = results_df['Hidden_Layers']
y_MAE = results_df['MAE']
plt.plot(X_plot,y_MAE)
```

[114]:
```
[<matplotlib.lines.Line2D at 0x7fe72411ba30>]
```



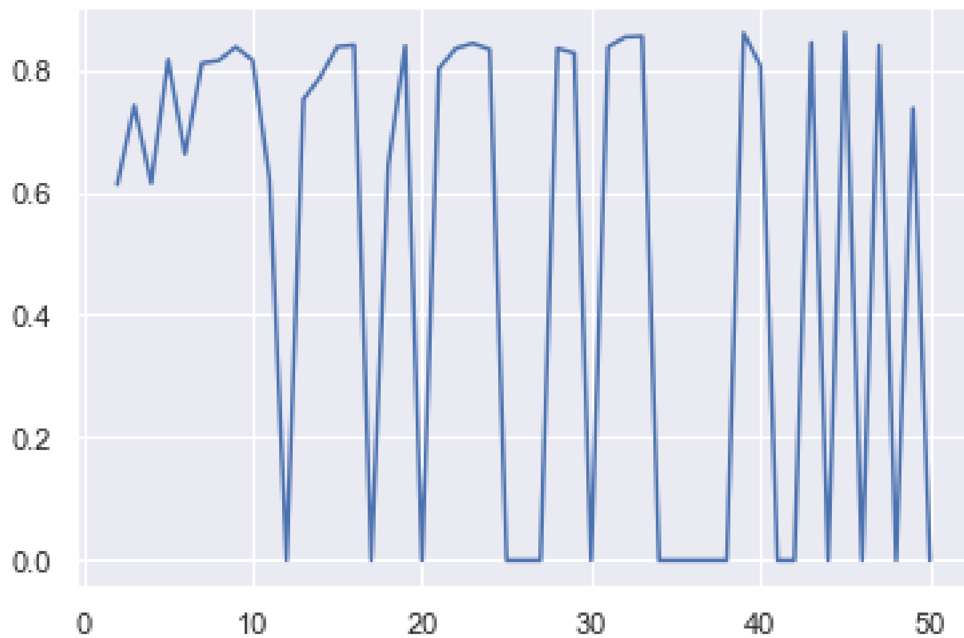

```
[115]: # Plot the root mean squared error for each iteration
       y_RMSE = results_df['RMSE']
       plt.plot(X_plot,y_RMSE)
```

```
[115]: [<matplotlib.lines.Line2D at 0x7fe725091400>]
```



[116]:
```
# Plot the explained variance score for each iteration
y_EVS = results_df['EVS']
plt.plot(X_plot,y_EVS)
```

[116]: [<matplotlib.lines.Line2D at 0x7fe725171550>]



[140]:
```
# Determine the minimum MAE, RMSE, and maximum EVS
results_df.describe()
```

[140]:

	Hidden_Layers	MAE	RMSE	EVS
count	49.00000	49.000000	49.000000	4.900000e+01
mean	26.00000	9.679436	11.720185	5.581656e-01
std	14.28869	7.974965	8.633592	3.607205e-01
min	2.00000	4.879614	6.234954	-2.562176e-08
25%	14.00000	5.533255	6.935423	0.000000e+00
50%	26.00000	6.057332	7.620311	7.755222e-01
75%	38.00000	13.041466	16.052520	8.195539e-01
max	50.00000	34.271702	37.844767	8.506060e-01

[141]:
```
# Iteration with the lowest MAE
results_df[results_df['MAE']<4.88]
```

[141]:

	Hidden_Layers	MAE	RMSE	EVS
43	45.0	4.879614	6.42268	0.841776

[142]:
```python
# Iteration with the lowest RMSE
results_df[results_df['RMSE']<6.24]
```

[142]:

	Hidden_Layers	MAE	RMSE	EVS
42	44.0	4.953943	6.234954	0.850606

[143]:
```python
# Iteration with the largest EVS
results_df[results_df['EVS']>0.85]
```

[143]:

	Hidden_Layers	MAE	RMSE	EVS
42	44.0	4.953943	6.234954	0.850606

We see that the minimum MAE is from 45 hidden layers, and the lowest RMSE and highest EVS are from 42 hidden layers. We will continue to work with the 44 hidden layer architecture.

1.9 Experimenting with the 44 Hidden Layer Model

There is an infinite number of possible configurations for a neural network. We will explore three below, keeping the 44 total hidden layers.

1.9.1 The Flat Model

[162]:
```python
optimization_results = []

model_flat = Sequential()
for i in range(45):
    model_flat.add(Dense(8,activation='relu'))
model_flat.add(Dense(1))

model_flat.compile(optimizer='adam',loss='mse')

# We will reset epochs to 200.
model_flat.fit(x=X_train,y=y_train.values,
      validation_data=(X_test,y_test.values),
      batch_size=128,epochs=200,verbose=0)

# Model evaluation
predictions_flat = model_flat.predict(X_test)

MAE_flat = mean_absolute_error(y_test,predictions_flat)
RMSE_flat = np.sqrt(mean_squared_error(y_test,predictions_flat))
EVS_flat = explained_variance_score(y_test,predictions_flat)

optimization_results.append(['Flat', MAE_flat,RMSE_flat,EVS_flat])

print(f"EVALUATION METRICS, HIDDEN LAYERS = 44")
print('-----------------------------')
```

```
print(f"Mean Absolute Error (MAE):\t\t{MAE_flat}\nRoot Mean Squared Error␣
↪(RMSE):\t\t{RMSE_flat}\nExplained Variance Score:\t\t{EVS_flat}")
print('-----------------------------\n\n')
```

```
EVALUATION METRICS, HIDDEN LAYERS = 44
-----------------------------
Mean Absolute Error (MAE):              5.08355243840264
Root Mean Squared Error (RMSE):         6.466492906453852
Explained Variance Score:               0.8383600376691335
-----------------------------
```

1.9.2 The Descending Model

[180]:
```
model_desc = Sequential()
for i in range(39):
    model_desc.add(Dense(8,activation='relu'))
model_desc.add(Dense(7,activation='relu'))
model_desc.add(Dense(6,activation='relu'))
model_desc.add(Dense(5,activation='relu'))
model_desc.add(Dense(4,activation='relu'))
model_desc.add(Dense(3,activation='relu'))
model_desc.add(Dense(2,activation='relu'))
model_desc.add(Dense(1))

model_desc.compile(optimizer='adam',loss='mse')

model_desc.fit(x=X_train,y=y_train.values,
      validation_data=(X_test,y_test.values),
      batch_size=128,epochs=200,verbose=0)

predictions_desc = model_desc.predict(X_test)

MAE_desc = mean_absolute_error(y_test,predictions_desc)
RMSE_desc = np.sqrt(mean_squared_error(y_test,predictions_desc))
EVS_desc = explained_variance_score(y_test,predictions_desc)

optimization_results.append(['Desc', MAE_desc,RMSE_desc,EVS_desc])

print(f"EVALUATION METRICS, HIDDEN LAYERS = 44, DESCENDING")
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_desc}\nRoot Mean Squared Error␣
↪(RMSE):\t\t{RMSE_desc}\nExplained Variance Score:\t\t{EVS_desc}")
print('-----------------------------\n\n')
```

```
EVALUATION METRICS, HIDDEN LAYERS = 44, DESCENDING
```

```
-----------------------------
Mean Absolute Error (MAE):             5.313633555532659
Root Mean Squared Error (RMSE):        6.834572877180595
Explained Variance Score:              0.8265445916481245
-----------------------------
```

[191]:
```python
# We can see that the descencing model performed worse than the flat model

optimization_df = pd.DataFrame(columns=['Model','MAE','RMSE','EVS'],data=np.
 ↪array(optimization_results))
optimization_df
```

[191]:

	Model	MAE	RMSE	EVS
0	Flat	5.08355243840264	6.466492906453852	0.8383600376691335
1	Desc	5.313633555532659	6.834572877180595	0.8265445916481245

1.9.3 The Flat Dropout Model

[202]:
```python
model_flat_drop = Sequential()

# Input layer
model_flat_drop.add(Dense(8,activation='relu'))

# Hidden Layers
for i in range(22): # Let's make half of the layers in the network dropout␣
 ↪layers at a 50% dropout rate
    model_flat_drop.add(Dense(8,activation='relu'))

    model_flat_drop.add(Dense(8,activation='relu'))
    model_flat_drop.add(Dropout(0.5))

# Output layer
model_flat_drop.add(Dense(1))

model_flat_drop.compile(optimizer='adam',loss='mse')

model_flat_drop.fit(x=X_train,y=y_train.values,
      validation_data=(X_test,y_test.values),
      batch_size=128,epochs=200,verbose=0)

# Model evaluation
predictions_flat_drop = model_flat_drop.predict(X_test)

MAE_flat_drop = mean_absolute_error(y_test,predictions_flat_drop)
RMSE_flat_drop = np.sqrt(mean_squared_error(y_test,predictions_flat_drop))
```

```
EVS_flat_drop = explained_variance_score(y_test,predictions_flat_drop)

optimization_results.append(['Flat_Drop',␣
↪MAE_flat_drop,RMSE_flat_drop,EVS_flat_drop])

print(f"EVALUATION METRICS, ACTIVE HIDDEN LAYERS = 22, DROPOUT HIDDEN LAYERS =␣
↪22")
print('-----------------------------')
print(f"Mean Absolute Error (MAE):\t\t{MAE_flat_drop}\nRoot Mean Squared Error␣
↪(RMSE):\t\t{RMSE_flat_drop}\nExplained Variance Score:\t\t{EVS_flat_drop}")
print('-----------------------------\n\n')
```

```
EVALUATION METRICS, ACTIVE HIDDEN LAYERS = 22, DROPOUT HIDDEN LAYERS = 22
-----------------------------
Mean Absolute Error (MAE):              18.2897413887098
Root Mean Squared Error (RMSE):         22.422906635113907
Explained Variance Score:               0.0
-----------------------------
```

1.10 Conclusions & Recommendations

We conclude that the "flat model" deep neural network containing 44 hidden layers of 8 nodes each, with no dropout nodes, is the optimal model from all the models tested in this project.

Additional models with different numbers of hidden layers and different architectures of the node networks could be subject to further experimentation and optimization. All three models containing the 44 hidden layers studied in this project are saved in the Keras_ANN_Models folder.

As discussed in the Exploratory Data Analysis code notebook, the compressive strength of concrete inreases rapidly from 0 to 28 days, then more much more stably from 28 days onward. A more intuitive and practical engineering model for predicting the compressive strength of concrete would rely on a given dataset containing only data of a certain curing time. Common testing times are at 3, 7, 14, 28, 60, 90, 128, and 365 days, with the 28 day mark being the industry standard. We analyze linear models at 28 days cure time in the Comparison with Linear Models notebook.

This dataset presented a unique challenge of predicting compressive strength not only as a function of its constituents, but also of time. The model in this project is able to predict the compressive strength of concrete to within a mean absolute error of 5.08 Megapascals (MPa), a root mean square error of 6.47 MPa, and an explained variance score of 0.838. The actual standard deviation for compressive strength in the dataset is 16.71 MPa. Therefore, the MAE is approximately 0.30 , and The RMSE is approximately 0.39 .

Given the high variance of the data, particularly in the 0 to 28 day range, these errors are reasonable. We recommend performing additional studies on larger datasets that represent a constant curing time, particularly the standard 28-day curing time, for the most practical engineering applications. Additional analysis comparing the ANN model with linear models is presented in the Model Analysis folder.