Course_1_Part_2_Lesson_2_Notebook

May 25, 2021


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```

1 The Hello World of Deep Learning with Neural Networks

Like every first app you should start with something super simple that shows the overall scaffolding for how your code works.

In the case of creating neural networks, the sample I like to use is one where it learns the relationship between two numbers. So, for example, if you were writing code for a function like this, you already know the 'rules' —

```
float hw_function(float x){
    float y = (2 * x) - 1;
    return y;
}
```

So how would you train a neural network to do the equivalent task? Using data! By feeding it with a set of Xs, and a set of Ys, it should be able to figure out the relationship between them.

This is obviously a very different paradigm than what you might be used to, so let's step through it piece by piece.

1.1 Imports

Let's start with our imports. Here we are importing TensorFlow and calling it tf for ease of use.

We then import a library called numpy, which helps us to represent our data as lists easily and quickly.

The framework for defining a neural network as a set of Sequential layers is called keras, so we import that too.

[1]:
```
import tensorflow as tf
import numpy as np
from tensorflow import keras
```

[3]:
```
print(tf.__version__)
print(keras.__version__)
```

```
2.5.0
2.5.0
```

1.2 Define and Compile the Neural Network

Next we will create the simplest possible neural network. It has 1 layer, and that layer has 1 neuron, and the input shape to it is just 1 value.

[2]:
```
model = tf.keras.Sequential([keras.layers.Dense(units=1, input_shape=[1])])
```

Now we compile our Neural Network. When we do so, we have to specify 2 functions, a loss and an optimizer.

If you've seen lots of math for machine learning, here's where it's usually used, but in this case it's nicely encapsulated in functions for you. But what happens here — let's explain…

We know that in our function, the relationship between the numbers is y=2x-1.

When the computer is trying to 'learn' that, it makes a guess…maybe y=10x+10. The LOSS function measures the guessed answers against the known correct answers and measures how well or how badly it did.

It then uses the OPTIMIZER function to make another guess. Based on how the loss function went, it will try to minimize the loss. At that point maybe it will come up with somehting like y=5x+5, which, while still pretty bad, is closer to the correct result (i.e. the loss is lower)

It will repeat this for the number of EPOCHS which you will see shortly. But first, here's how we tell it to use 'MEAN SQUARED ERROR' for the loss and 'STOCHASTIC GRADIENT DESCENT' for the optimizer. You don't need to understand the math for these yet, but you can see that they work! :)

Over time you will learn the different and appropriate loss and optimizer functions for different scenarios.

[4]:
```
model.compile(optimizer='sgd', loss='mean_squared_error')
```

1.3 Providing the Data

Next up we'll feed in some data. In this case we are taking 6 xs and 6ys. You can see that the relationship between these is that y=2x-1, so where x = -1, y=-3 etc. etc.

A python library called 'Numpy' provides lots of array type data structures that are a defacto standard way of doing it. We declare that we want to use these by specifying the values as an np.array[]

[5]:
```
xs = np.array([-1.0,  0.0, 1.0, 2.0, 3.0, 4.0], dtype=float)
ys = np.array([-3.0, -1.0, 1.0, 3.0, 5.0, 7.0], dtype=float)
```

2 Training the Neural Network

The process of training the neural network, where it 'learns' the relationship between the Xs and Ys is in the **model.fit** call. This is where it will go through the loop we spoke about above, making a guess, measuring how good or bad it is (aka the loss), using the opimizer to make another guess etc. It will do it for the number of epochs you specify. When you run this code, you'll see the loss on the right hand side.

[6]:
```
model.fit(xs, ys, epochs=500)
```

```
Epoch 1/500
1/1 [==============================] - 0s 411ms/step - loss: 27.5590
Epoch 2/500
1/1 [==============================] - 0s 7ms/step - loss: 21.9841
Epoch 3/500
1/1 [==============================] - 0s 4ms/step - loss: 17.5918
Epoch 4/500
1/1 [==============================] - 0s 5ms/step - loss: 14.1302
Epoch 5/500
1/1 [==============================] - 0s 4ms/step - loss: 11.4007
Epoch 6/500
1/1 [==============================] - 0s 5ms/step - loss: 9.2475
Epoch 7/500
1/1 [==============================] - 0s 5ms/step - loss: 7.5478
Epoch 8/500
1/1 [==============================] - 0s 4ms/step - loss: 6.2049
Epoch 9/500
1/1 [==============================] - 0s 6ms/step - loss: 5.1429
Epoch 10/500
1/1 [==============================] - 0s 6ms/step - loss: 4.3020
Epoch 11/500
1/1 [==============================] - 0s 7ms/step - loss: 3.6352
Epoch 12/500
1/1 [==============================] - 0s 6ms/step - loss: 3.1054
Epoch 13/500
```

```
1/1 [==============================] - 0s 5ms/step - loss: 2.6836
Epoch 14/500
1/1 [==============================] - 0s 5ms/step - loss: 2.3467
Epoch 15/500
1/1 [==============================] - 0s 5ms/step - loss: 2.0769
Epoch 16/500
1/1 [==============================] - 0s 7ms/step - loss: 1.8599
Epoch 17/500
1/1 [==============================] - 0s 5ms/step - loss: 1.6845
Epoch 18/500
1/1 [==============================] - 0s 3ms/step - loss: 1.5420
Epoch 19/500
1/1 [==============================] - 0s 3ms/step - loss: 1.4254
Epoch 20/500
1/1 [==============================] - 0s 3ms/step - loss: 1.3293
Epoch 21/500
1/1 [==============================] - 0s 5ms/step - loss: 1.2494
Epoch 22/500
1/1 [==============================] - 0s 5ms/step - loss: 1.1824
Epoch 23/500
1/1 [==============================] - 0s 4ms/step - loss: 1.1256
Epoch 24/500
1/1 [==============================] - 0s 4ms/step - loss: 1.0769
Epoch 25/500
1/1 [==============================] - 0s 14ms/step - loss: 1.0346
Epoch 26/500
1/1 [==============================] - 0s 5ms/step - loss: 0.9975
Epoch 27/500
1/1 [==============================] - 0s 5ms/step - loss: 0.9646
Epoch 28/500
1/1 [==============================] - 0s 6ms/step - loss: 0.9350
Epoch 29/500
1/1 [==============================] - 0s 4ms/step - loss: 0.9080
Epoch 30/500
1/1 [==============================] - 0s 4ms/step - loss: 0.8833
Epoch 31/500
1/1 [==============================] - 0s 4ms/step - loss: 0.8604
Epoch 32/500
1/1 [==============================] - 0s 4ms/step - loss: 0.8390
Epoch 33/500
1/1 [==============================] - 0s 3ms/step - loss: 0.8188
Epoch 34/500
1/1 [==============================] - 0s 3ms/step - loss: 0.7996
Epoch 35/500
1/1 [==============================] - 0s 4ms/step - loss: 0.7814
Epoch 36/500
1/1 [==============================] - 0s 7ms/step - loss: 0.7639
Epoch 37/500
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1/1 [==============================] - 0s 5ms/step - loss: 0.7471
Epoch 38/500
1/1 [==============================] - 0s 5ms/step - loss: 0.7308
Epoch 39/500
1/1 [==============================] - 0s 4ms/step - loss: 0.7151
Epoch 40/500
1/1 [==============================] - 0s 4ms/step - loss: 0.6999
Epoch 41/500
1/1 [==============================] - 0s 5ms/step - loss: 0.6851
Epoch 42/500
1/1 [==============================] - 0s 4ms/step - loss: 0.6707
Epoch 43/500
1/1 [==============================] - 0s 9ms/step - loss: 0.6566
Epoch 44/500
1/1 [==============================] - 0s 7ms/step - loss: 0.6429
Epoch 45/500
1/1 [==============================] - 0s 5ms/step - loss: 0.6295
Epoch 46/500
1/1 [==============================] - 0s 5ms/step - loss: 0.6165
Epoch 47/500
1/1 [==============================] - 0s 4ms/step - loss: 0.6037
Epoch 48/500
1/1 [==============================] - 0s 8ms/step - loss: 0.5912
Epoch 49/500
1/1 [==============================] - 0s 5ms/step - loss: 0.5790
Epoch 50/500
1/1 [==============================] - 0s 4ms/step - loss: 0.5671
Epoch 51/500
1/1 [==============================] - 0s 4ms/step - loss: 0.5554
Epoch 52/500
1/1 [==============================] - 0s 5ms/step - loss: 0.5440
Epoch 53/500
1/1 [==============================] - 0s 4ms/step - loss: 0.5328
Epoch 54/500
1/1 [==============================] - 0s 3ms/step - loss: 0.5218
Epoch 55/500
1/1 [==============================] - 0s 3ms/step - loss: 0.5111
Epoch 56/500
1/1 [==============================] - 0s 6ms/step - loss: 0.5005
Epoch 57/500
1/1 [==============================] - 0s 5ms/step - loss: 0.4903
Epoch 58/500
1/1 [==============================] - 0s 5ms/step - loss: 0.4802
Epoch 59/500
1/1 [==============================] - 0s 4ms/step - loss: 0.4703
Epoch 60/500
1/1 [==============================] - 0s 7ms/step - loss: 0.4606
Epoch 61/500
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```
1/1 [==============================] - 0s 7ms/step - loss: 0.4512
Epoch 62/500
1/1 [==============================] - 0s 3ms/step - loss: 0.4419
Epoch 63/500
1/1 [==============================] - 0s 4ms/step - loss: 0.4328
Epoch 64/500
1/1 [==============================] - 0s 4ms/step - loss: 0.4239
Epoch 65/500
1/1 [==============================] - 0s 4ms/step - loss: 0.4152
Epoch 66/500
1/1 [==============================] - 0s 6ms/step - loss: 0.4067
Epoch 67/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3983
Epoch 68/500
1/1 [==============================] - 0s 4ms/step - loss: 0.3902
Epoch 69/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3821
Epoch 70/500
1/1 [==============================] - 0s 16ms/step - loss: 0.3743
Epoch 71/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3666
Epoch 72/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3591
Epoch 73/500
1/1 [==============================] - 0s 4ms/step - loss: 0.3517
Epoch 74/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3445
Epoch 75/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3374
Epoch 76/500
1/1 [==============================] - 0s 4ms/step - loss: 0.3305
Epoch 77/500
1/1 [==============================] - 0s 4ms/step - loss: 0.3237
Epoch 78/500
1/1 [==============================] - 0s 6ms/step - loss: 0.3170
Epoch 79/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3105
Epoch 80/500
1/1 [==============================] - 0s 3ms/step - loss: 0.3041
Epoch 81/500
1/1 [==============================] - 0s 4ms/step - loss: 0.2979
Epoch 82/500
1/1 [==============================] - 0s 3ms/step - loss: 0.2918
Epoch 83/500
1/1 [==============================] - 0s 3ms/step - loss: 0.2858
Epoch 84/500
1/1 [==============================] - 0s 3ms/step - loss: 0.2799
Epoch 85/500
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1/1 [==============================] - 0s 4ms/step - loss: 0.2742
Epoch 86/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2685
Epoch 87/500
1/1 [==============================] - 0s 4ms/step - loss: 0.2630
Epoch 88/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2576
Epoch 89/500
1/1 [==============================] - 0s 6ms/step - loss: 0.2523
Epoch 90/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2471
Epoch 91/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2421
Epoch 92/500
1/1 [==============================] - 0s 6ms/step - loss: 0.2371
Epoch 93/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2322
Epoch 94/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2275
Epoch 95/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2228
Epoch 96/500
1/1 [==============================] - 0s 5ms/step - loss: 0.2182
Epoch 97/500
1/1 [==============================] - 0s 4ms/step - loss: 0.2137
Epoch 98/500
1/1 [==============================] - 0s 6ms/step - loss: 0.2093
Epoch 99/500
1/1 [==============================] - 0s 4ms/step - loss: 0.2050
Epoch 100/500
1/1 [==============================] - 0s 7ms/step - loss: 0.2008
Epoch 101/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1967
Epoch 102/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1927
Epoch 103/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1887
Epoch 104/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1848
Epoch 105/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1810
Epoch 106/500
1/1 [==============================] - 0s 47ms/step - loss: 0.1773
Epoch 107/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1737
Epoch 108/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1701
Epoch 109/500
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1/1 [==============================] - 0s 7ms/step - loss: 0.1666
Epoch 110/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1632
Epoch 111/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1598
Epoch 112/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1565
Epoch 113/500
1/1 [==============================] - 0s 6ms/step - loss: 0.1533
Epoch 114/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1502
Epoch 115/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1471
Epoch 116/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1441
Epoch 117/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1411
Epoch 118/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1382
Epoch 119/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1354
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1/1 [==============================] - 0s 7ms/step - loss: 0.1326
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1/1 [==============================] - 0s 4ms/step - loss: 0.1299
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1/1 [==============================] - 0s 3ms/step - loss: 0.1272
Epoch 123/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1246
Epoch 124/500
1/1 [==============================] - 0s 6ms/step - loss: 0.1220
Epoch 125/500
1/1 [==============================] - 0s 3ms/step - loss: 0.1195
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1/1 [==============================] - 0s 4ms/step - loss: 0.1171
Epoch 127/500
1/1 [==============================] - 0s 5ms/step - loss: 0.1147
Epoch 128/500
1/1 [==============================] - 0s 4ms/step - loss: 0.1123
Epoch 129/500
1/1 [==============================] - 0s 5ms/step - loss: 0.1100
Epoch 130/500
1/1 [==============================] - 0s 12ms/step - loss: 0.1077
Epoch 131/500
1/1 [==============================] - 0s 5ms/step - loss: 0.1055
Epoch 132/500
1/1 [==============================] - 0s 17ms/step - loss: 0.1034
Epoch 133/500
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1/1 [==============================] - 0s 6ms/step - loss: 0.1012
Epoch 134/500
1/1 [==============================] - 0s 13ms/step - loss: 0.0992
Epoch 135/500
1/1 [==============================] - 0s 13ms/step - loss: 0.0971
Epoch 136/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0951
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Epoch 138/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0913
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1/1 [==============================] - 0s 7ms/step - loss: 0.0894
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1/1 [==============================] - 0s 12ms/step - loss: 0.0876
Epoch 141/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0858
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1/1 [==============================] - 0s 5ms/step - loss: 0.0840
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1/1 [==============================] - 0s 8ms/step - loss: 0.0823
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1/1 [==============================] - 0s 21ms/step - loss: 0.0806
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1/1 [==============================] - 0s 14ms/step - loss: 0.0789
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1/1 [==============================] - 0s 4ms/step - loss: 0.0773
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1/1 [==============================] - 0s 3ms/step - loss: 0.0742
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1/1 [==============================] - 0s 4ms/step - loss: 0.0711
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1/1 [==============================] - 0s 4ms/step - loss: 0.0697
Epoch 152/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0683
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1/1 [==============================] - 0s 8ms/step - loss: 0.0655
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1/1 [==============================] - 0s 4ms/step - loss: 0.0641
Epoch 156/500
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Epoch 157/500
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1/1 [==============================] - 0s 4ms/step - loss: 0.0615
Epoch 158/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0603
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1/1 [==============================] - 0s 6ms/step - loss: 0.0590
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1/1 [==============================] - 0s 4ms/step - loss: 0.0578
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1/1 [==============================] - 0s 5ms/step - loss: 0.0566
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1/1 [==============================] - 0s 5ms/step - loss: 0.0521
Epoch 166/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0510
Epoch 167/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0500
Epoch 168/500
1/1 [==============================] - 0s 125ms/step - loss: 0.0490
Epoch 169/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0480
Epoch 170/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0470
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1/1 [==============================] - 0s 4ms/step - loss: 0.0460
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1/1 [==============================] - 0s 7ms/step - loss: 0.0451
Epoch 173/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0441
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Epoch 178/500
1/1 [==============================] - 0s 10ms/step - loss: 0.0398
Epoch 179/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0390
Epoch 180/500
1/1 [==============================] - 0s 9ms/step - loss: 0.0382
Epoch 181/500
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1/1 [==============================] - 0s 6ms/step - loss: 0.0374
Epoch 182/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0366
Epoch 183/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0359
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1/1 [==============================] - 0s 9ms/step - loss: 0.0323
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1/1 [==============================] - 0s 21ms/step - loss: 0.0317
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1/1 [==============================] - 0s 10ms/step - loss: 0.0310
Epoch 191/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0304
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1/1 [==============================] - 0s 5ms/step - loss: 0.0298
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1/1 [==============================] - 0s 5ms/step - loss: 0.0291
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1/1 [==============================] - 0s 4ms/step - loss: 0.0280
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1/1 [==============================] - 0s 7ms/step - loss: 0.0274
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Epoch 199/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0257
Epoch 200/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0252
Epoch 201/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0247
Epoch 202/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0242
Epoch 203/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0237
Epoch 204/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0232
Epoch 205/500
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1/1 [==============================] - 0s 4ms/step - loss: 0.0227
Epoch 206/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0223
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Epoch 208/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0213
Epoch 209/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0209
Epoch 210/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0205
Epoch 211/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0201
Epoch 212/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0196
Epoch 213/500
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Epoch 215/500
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Epoch 216/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0181
Epoch 217/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0177
Epoch 218/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0173
Epoch 219/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0170
Epoch 220/500
1/1 [==============================] - 0s 17ms/step - loss: 0.0166
Epoch 221/500
1/1 [==============================] - 0s 25ms/step - loss: 0.0163
Epoch 222/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0160
Epoch 223/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0156
Epoch 224/500
1/1 [==============================] - 0s 24ms/step - loss: 0.0153
Epoch 225/500
1/1 [==============================] - 0s 15ms/step - loss: 0.0150
Epoch 226/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0147
Epoch 227/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0144
Epoch 228/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0141
Epoch 229/500
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1/1 [==============================] - 0s 6ms/step - loss: 0.0138
Epoch 230/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0135
Epoch 231/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0132
Epoch 232/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0130
Epoch 233/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0127
Epoch 234/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0124
Epoch 235/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0122
Epoch 236/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0119
Epoch 237/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0117
Epoch 238/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0115
Epoch 239/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0112
Epoch 240/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0110
Epoch 241/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0108
Epoch 242/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0105
Epoch 243/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0103
Epoch 244/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0101
Epoch 245/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0099
Epoch 246/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0097
Epoch 247/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0095
Epoch 248/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0093
Epoch 249/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0091
Epoch 250/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0089
Epoch 251/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0087
Epoch 252/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0086
Epoch 253/500
```

```
1/1 [==============================] - 0s 6ms/step - loss: 0.0084
Epoch 254/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0082
Epoch 255/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0080
Epoch 256/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0079
Epoch 257/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0077
Epoch 258/500
1/1 [==============================] - 0s 9ms/step - loss: 0.0076
Epoch 259/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0074
Epoch 260/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0073
Epoch 261/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0071
Epoch 262/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0070
Epoch 263/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0068
Epoch 264/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0067
Epoch 265/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0065
Epoch 266/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0064
Epoch 267/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0063
Epoch 268/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0061
Epoch 269/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0060
Epoch 270/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0059
Epoch 271/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0058
Epoch 272/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0057
Epoch 273/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0055
Epoch 274/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0054
Epoch 275/500
1/1 [==============================] - 0s 12ms/step - loss: 0.0053
Epoch 276/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0052
Epoch 277/500
```

```
1/1 [==============================] - 0s 7ms/step - loss: 0.0051
Epoch 278/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0050
Epoch 279/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0049
Epoch 280/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0048
Epoch 281/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0047
Epoch 282/500
1/1 [==============================] - 0s 12ms/step - loss: 0.0046
Epoch 283/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0045
Epoch 284/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0044
Epoch 285/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0043
Epoch 286/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0042
Epoch 287/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0041
Epoch 288/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0041
Epoch 289/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0040
Epoch 290/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0039
Epoch 291/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0038
Epoch 292/500
1/1 [==============================] - 0s 91ms/step - loss: 0.0037
Epoch 293/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0037
Epoch 294/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0036
Epoch 295/500
1/1 [==============================] - 0s 19ms/step - loss: 0.0035
Epoch 296/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0034
Epoch 297/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0034
Epoch 298/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0033
Epoch 299/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0032
Epoch 300/500
1/1 [==============================] - 0s 10ms/step - loss: 0.0032
Epoch 301/500
```

```
1/1 [==============================] - 0s 26ms/step - loss: 0.0031
Epoch 302/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0030
Epoch 303/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0030
Epoch 304/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0029
Epoch 305/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0029
Epoch 306/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0028
Epoch 307/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0027
Epoch 308/500
1/1 [==============================] - 0s 11ms/step - loss: 0.0027
Epoch 309/500
1/1 [==============================] - 0s 11ms/step - loss: 0.0026
Epoch 310/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0026
Epoch 311/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0025
Epoch 312/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0025
Epoch 313/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0024
Epoch 314/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0024
Epoch 315/500
1/1 [==============================] - 0s 10ms/step - loss: 0.0023
Epoch 316/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0023
Epoch 317/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0022
Epoch 318/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0022
Epoch 319/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0021
Epoch 320/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0021
Epoch 321/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0020
Epoch 322/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0020
Epoch 323/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0020
Epoch 324/500
1/1 [==============================] - 0s 3ms/step - loss: 0.0019
Epoch 325/500
```

```
1/1 [==============================] - 0s 8ms/step - loss: 0.0019
Epoch 326/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0018
Epoch 327/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0018
Epoch 328/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0018
Epoch 329/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0017
Epoch 330/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0017
Epoch 331/500
1/1 [==============================] - 0s 12ms/step - loss: 0.0017
Epoch 332/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0016
Epoch 333/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0016
Epoch 334/500
1/1 [==============================] - 0s 10ms/step - loss: 0.0016
Epoch 335/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0015
Epoch 336/500
1/1 [==============================] - 0s 12ms/step - loss: 0.0015
Epoch 337/500
1/1 [==============================] - 0s 11ms/step - loss: 0.0015
Epoch 338/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0014
Epoch 339/500
1/1 [==============================] - 0s 18ms/step - loss: 0.0014
Epoch 340/500
1/1 [==============================] - 0s 12ms/step - loss: 0.0014
Epoch 341/500
1/1 [==============================] - 0s 8ms/step - loss: 0.0014
Epoch 342/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0013
Epoch 343/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0013
Epoch 344/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0013
Epoch 345/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0012
Epoch 346/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0012
Epoch 347/500
1/1 [==============================] - 0s 5ms/step - loss: 0.0012
Epoch 348/500
1/1 [==============================] - 0s 7ms/step - loss: 0.0012
Epoch 349/500
```

```
1/1 [==============================] - 0s 4ms/step - loss: 0.0011
Epoch 350/500
1/1 [==============================] - 0s 6ms/step - loss: 0.0011
Epoch 351/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0011
Epoch 352/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0011
Epoch 353/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0011
Epoch 354/500
1/1 [==============================] - 0s 4ms/step - loss: 0.0010
Epoch 355/500
1/1 [==============================] - 0s 10ms/step - loss: 0.0010
Epoch 356/500
1/1 [==============================] - 0s 7ms/step - loss: 9.8931e-04
Epoch 357/500
1/1 [==============================] - 0s 7ms/step - loss: 9.6899e-04
Epoch 358/500
1/1 [==============================] - 0s 5ms/step - loss: 9.4908e-04
Epoch 359/500
1/1 [==============================] - 0s 4ms/step - loss: 9.2959e-04
Epoch 360/500
1/1 [==============================] - 0s 6ms/step - loss: 9.1050e-04
Epoch 361/500
1/1 [==============================] - 0s 4ms/step - loss: 8.9180e-04
Epoch 362/500
1/1 [==============================] - 0s 5ms/step - loss: 8.7348e-04
Epoch 363/500
1/1 [==============================] - 0s 10ms/step - loss: 8.5554e-04
Epoch 364/500
1/1 [==============================] - 0s 4ms/step - loss: 8.3796e-04
Epoch 365/500
1/1 [==============================] - 0s 4ms/step - loss: 8.2075e-04
Epoch 366/500
1/1 [==============================] - 0s 4ms/step - loss: 8.0389e-04
Epoch 367/500
1/1 [==============================] - 0s 3ms/step - loss: 7.8738e-04
Epoch 368/500
1/1 [==============================] - 0s 8ms/step - loss: 7.7121e-04
Epoch 369/500
1/1 [==============================] - 0s 4ms/step - loss: 7.5536e-04
Epoch 370/500
1/1 [==============================] - 0s 4ms/step - loss: 7.3985e-04
Epoch 371/500
1/1 [==============================] - 0s 3ms/step - loss: 7.2465e-04
Epoch 372/500
1/1 [==============================] - 0s 3ms/step - loss: 7.0977e-04
Epoch 373/500
```

```
1/1 [==============================] - 0s 3ms/step - loss: 6.9518e-04
Epoch 374/500
1/1 [==============================] - 0s 4ms/step - loss: 6.8090e-04
Epoch 375/500
1/1 [==============================] - 0s 3ms/step - loss: 6.6692e-04
Epoch 376/500
1/1 [==============================] - 0s 5ms/step - loss: 6.5322e-04
Epoch 377/500
1/1 [==============================] - 0s 4ms/step - loss: 6.3980e-04
Epoch 378/500
1/1 [==============================] - 0s 6ms/step - loss: 6.2666e-04
Epoch 379/500
1/1 [==============================] - 0s 3ms/step - loss: 6.1379e-04
Epoch 380/500
1/1 [==============================] - 0s 8ms/step - loss: 6.0118e-04
Epoch 381/500
1/1 [==============================] - 0s 3ms/step - loss: 5.8884e-04
Epoch 382/500
1/1 [==============================] - 0s 3ms/step - loss: 5.7674e-04
Epoch 383/500
1/1 [==============================] - 0s 4ms/step - loss: 5.6489e-04
Epoch 384/500
1/1 [==============================] - 0s 3ms/step - loss: 5.5329e-04
Epoch 385/500
1/1 [==============================] - 0s 3ms/step - loss: 5.4192e-04
Epoch 386/500
1/1 [==============================] - 0s 6ms/step - loss: 5.3079e-04
Epoch 387/500
1/1 [==============================] - 0s 5ms/step - loss: 5.1989e-04
Epoch 388/500
1/1 [==============================] - 0s 4ms/step - loss: 5.0921e-04
Epoch 389/500
1/1 [==============================] - 0s 3ms/step - loss: 4.9875e-04
Epoch 390/500
1/1 [==============================] - 0s 3ms/step - loss: 4.8851e-04
Epoch 391/500
1/1 [==============================] - 0s 4ms/step - loss: 4.7847e-04
Epoch 392/500
1/1 [==============================] - 0s 3ms/step - loss: 4.6865e-04
Epoch 393/500
1/1 [==============================] - 0s 5ms/step - loss: 4.5902e-04
Epoch 394/500
1/1 [==============================] - 0s 3ms/step - loss: 4.4959e-04
Epoch 395/500
1/1 [==============================] - 0s 6ms/step - loss: 4.4035e-04
Epoch 396/500
1/1 [==============================] - 0s 4ms/step - loss: 4.3131e-04
Epoch 397/500
```

```
1/1 [==============================] - 0s 4ms/step - loss: 4.2245e-04
Epoch 398/500
1/1 [==============================] - 0s 5ms/step - loss: 4.1377e-04
Epoch 399/500
1/1 [==============================] - 0s 3ms/step - loss: 4.0527e-04
Epoch 400/500
1/1 [==============================] - 0s 5ms/step - loss: 3.9695e-04
Epoch 401/500
1/1 [==============================] - 0s 3ms/step - loss: 3.8879e-04
Epoch 402/500
1/1 [==============================] - 0s 3ms/step - loss: 3.8081e-04
Epoch 403/500
1/1 [==============================] - 0s 4ms/step - loss: 3.7299e-04
Epoch 404/500
1/1 [==============================] - 0s 5ms/step - loss: 3.6533e-04
Epoch 405/500
1/1 [==============================] - 0s 5ms/step - loss: 3.5782e-04
Epoch 406/500
1/1 [==============================] - 0s 3ms/step - loss: 3.5047e-04
Epoch 407/500
1/1 [==============================] - 0s 5ms/step - loss: 3.4327e-04
Epoch 408/500
1/1 [==============================] - 0s 11ms/step - loss: 3.3622e-04
Epoch 409/500
1/1 [==============================] - 0s 15ms/step - loss: 3.2931e-04
Epoch 410/500
1/1 [==============================] - 0s 28ms/step - loss: 3.2255e-04
Epoch 411/500
1/1 [==============================] - 0s 41ms/step - loss: 3.1592e-04
Epoch 412/500
1/1 [==============================] - 0s 37ms/step - loss: 3.0944e-04
Epoch 413/500
1/1 [==============================] - 0s 9ms/step - loss: 3.0308e-04
Epoch 414/500
1/1 [==============================] - 0s 10ms/step - loss: 2.9685e-04
Epoch 415/500
1/1 [==============================] - 0s 6ms/step - loss: 2.9076e-04
Epoch 416/500
1/1 [==============================] - 0s 9ms/step - loss: 2.8478e-04
Epoch 417/500
1/1 [==============================] - 0s 7ms/step - loss: 2.7893e-04
Epoch 418/500
1/1 [==============================] - 0s 5ms/step - loss: 2.7320e-04
Epoch 419/500
1/1 [==============================] - 0s 3ms/step - loss: 2.6759e-04
Epoch 420/500
1/1 [==============================] - 0s 5ms/step - loss: 2.6210e-04
Epoch 421/500
```

```
1/1 [==============================] - 0s 4ms/step - loss: 2.5671e-04
Epoch 422/500
1/1 [==============================] - 0s 16ms/step - loss: 2.5144e-04
Epoch 423/500
1/1 [==============================] - 0s 6ms/step - loss: 2.4628e-04
Epoch 424/500
1/1 [==============================] - 0s 5ms/step - loss: 2.4122e-04
Epoch 425/500
1/1 [==============================] - 0s 5ms/step - loss: 2.3626e-04
Epoch 426/500
1/1 [==============================] - 0s 6ms/step - loss: 2.3141e-04
Epoch 427/500
1/1 [==============================] - 0s 3ms/step - loss: 2.2666e-04
Epoch 428/500
1/1 [==============================] - 0s 10ms/step - loss: 2.2200e-04
Epoch 429/500
1/1 [==============================] - 0s 4ms/step - loss: 2.1744e-04
Epoch 430/500
1/1 [==============================] - 0s 5ms/step - loss: 2.1297e-04
Epoch 431/500
1/1 [==============================] - 0s 4ms/step - loss: 2.0860e-04
Epoch 432/500
1/1 [==============================] - 0s 6ms/step - loss: 2.0431e-04
Epoch 433/500
1/1 [==============================] - 0s 3ms/step - loss: 2.0012e-04
Epoch 434/500
1/1 [==============================] - 0s 3ms/step - loss: 1.9601e-04
Epoch 435/500
1/1 [==============================] - 0s 3ms/step - loss: 1.9198e-04
Epoch 436/500
1/1 [==============================] - 0s 5ms/step - loss: 1.8804e-04
Epoch 437/500
1/1 [==============================] - 0s 5ms/step - loss: 1.8417e-04
Epoch 438/500
1/1 [==============================] - 0s 3ms/step - loss: 1.8039e-04
Epoch 439/500
1/1 [==============================] - 0s 5ms/step - loss: 1.7669e-04
Epoch 440/500
1/1 [==============================] - 0s 4ms/step - loss: 1.7306e-04
Epoch 441/500
1/1 [==============================] - 0s 5ms/step - loss: 1.6950e-04
Epoch 442/500
1/1 [==============================] - 0s 3ms/step - loss: 1.6602e-04
Epoch 443/500
1/1 [==============================] - 0s 7ms/step - loss: 1.6261e-04
Epoch 444/500
1/1 [==============================] - 0s 4ms/step - loss: 1.5927e-04
Epoch 445/500
```

```
1/1 [==============================] - 0s 4ms/step - loss: 1.5600e-04
Epoch 446/500
1/1 [==============================] - 0s 7ms/step - loss: 1.5279e-04
Epoch 447/500
1/1 [==============================] - 0s 3ms/step - loss: 1.4965e-04
Epoch 448/500
1/1 [==============================] - 0s 5ms/step - loss: 1.4658e-04
Epoch 449/500
1/1 [==============================] - 0s 4ms/step - loss: 1.4357e-04
Epoch 450/500
1/1 [==============================] - 0s 12ms/step - loss: 1.4062e-04
Epoch 451/500
1/1 [==============================] - 0s 12ms/step - loss: 1.3773e-04
Epoch 452/500
1/1 [==============================] - 0s 16ms/step - loss: 1.3490e-04
Epoch 453/500
1/1 [==============================] - 0s 5ms/step - loss: 1.3213e-04
Epoch 454/500
1/1 [==============================] - 0s 4ms/step - loss: 1.2942e-04
Epoch 455/500
1/1 [==============================] - 0s 4ms/step - loss: 1.2676e-04
Epoch 456/500
1/1 [==============================] - 0s 5ms/step - loss: 1.2415e-04
Epoch 457/500
1/1 [==============================] - 0s 6ms/step - loss: 1.2161e-04
Epoch 458/500
1/1 [==============================] - 0s 4ms/step - loss: 1.1911e-04
Epoch 459/500
1/1 [==============================] - 0s 5ms/step - loss: 1.1666e-04
Epoch 460/500
1/1 [==============================] - 0s 5ms/step - loss: 1.1427e-04
Epoch 461/500
1/1 [==============================] - 0s 7ms/step - loss: 1.1192e-04
Epoch 462/500
1/1 [==============================] - 0s 4ms/step - loss: 1.0962e-04
Epoch 463/500
1/1 [==============================] - 0s 3ms/step - loss: 1.0737e-04
Epoch 464/500
1/1 [==============================] - 0s 5ms/step - loss: 1.0516e-04
Epoch 465/500
1/1 [==============================] - 0s 5ms/step - loss: 1.0300e-04
Epoch 466/500
1/1 [==============================] - 0s 5ms/step - loss: 1.0089e-04
Epoch 467/500
1/1 [==============================] - 0s 5ms/step - loss: 9.8814e-05
Epoch 468/500
1/1 [==============================] - 0s 16ms/step - loss: 9.6784e-05
Epoch 469/500
```

```
1/1 [==============================] - 0s 7ms/step - loss: 9.4797e-05
Epoch 470/500
1/1 [==============================] - 0s 4ms/step - loss: 9.2850e-05
Epoch 471/500
1/1 [==============================] - 0s 5ms/step - loss: 9.0943e-05
Epoch 472/500
1/1 [==============================] - 0s 8ms/step - loss: 8.9074e-05
Epoch 473/500
1/1 [==============================] - 0s 7ms/step - loss: 8.7246e-05
Epoch 474/500
1/1 [==============================] - 0s 4ms/step - loss: 8.5454e-05
Epoch 475/500
1/1 [==============================] - 0s 4ms/step - loss: 8.3698e-05
Epoch 476/500
1/1 [==============================] - 0s 5ms/step - loss: 8.1979e-05
Epoch 477/500
1/1 [==============================] - 0s 4ms/step - loss: 8.0295e-05
Epoch 478/500
1/1 [==============================] - 0s 82ms/step - loss: 7.8646e-05
Epoch 479/500
1/1 [==============================] - 0s 4ms/step - loss: 7.7029e-05
Epoch 480/500
1/1 [==============================] - 0s 4ms/step - loss: 7.5447e-05
Epoch 481/500
1/1 [==============================] - 0s 5ms/step - loss: 7.3898e-05
Epoch 482/500
1/1 [==============================] - 0s 3ms/step - loss: 7.2380e-05
Epoch 483/500
1/1 [==============================] - 0s 4ms/step - loss: 7.0893e-05
Epoch 484/500
1/1 [==============================] - 0s 4ms/step - loss: 6.9436e-05
Epoch 485/500
1/1 [==============================] - 0s 3ms/step - loss: 6.8010e-05
Epoch 486/500
1/1 [==============================] - 0s 4ms/step - loss: 6.6614e-05
Epoch 487/500
1/1 [==============================] - 0s 6ms/step - loss: 6.5245e-05
Epoch 488/500
1/1 [==============================] - 0s 4ms/step - loss: 6.3905e-05
Epoch 489/500
1/1 [==============================] - 0s 3ms/step - loss: 6.2592e-05
Epoch 490/500
1/1 [==============================] - 0s 3ms/step - loss: 6.1307e-05
Epoch 491/500
1/1 [==============================] - 0s 7ms/step - loss: 6.0046e-05
Epoch 492/500
1/1 [==============================] - 0s 3ms/step - loss: 5.8813e-05
Epoch 493/500
```

```
1/1 [==============================] - 0s 4ms/step - loss: 5.7604e-05
Epoch 494/500
1/1 [==============================] - 0s 3ms/step - loss: 5.6422e-05
Epoch 495/500
1/1 [==============================] - 0s 3ms/step - loss: 5.5263e-05
Epoch 496/500
1/1 [==============================] - 0s 3ms/step - loss: 5.4128e-05
Epoch 497/500
1/1 [==============================] - 0s 5ms/step - loss: 5.3016e-05
Epoch 498/500
1/1 [==============================] - 0s 9ms/step - loss: 5.1927e-05
Epoch 499/500
1/1 [==============================] - 0s 3ms/step - loss: 5.0860e-05
Epoch 500/500
1/1 [==============================] - 0s 3ms/step - loss: 4.9815e-05
```

[6]: `<tensorflow.python.keras.callbacks.History at 0x7f72abe5c050>`

Ok, now you have a model that has been trained to learn the relationship between X and Y. You can use the **model.predict** method to have it figure out the Y for a previously unknown X. So, for example, if X = 10, what do you think Y will be? Take a guess before you run this code:

[7]:
```
print(model.predict([10.0]))
```

```
[[18.979408]]
```

You might have thought 19, right? But it ended up being a little under. Why do you think that is?

Remember that neural networks deal with probabilities, so given the data that we fed the NN with, it calculated that there is a very high probability that the relationship between X and Y is Y=2X-1, but with only 6 data points we can't know for sure. As a result, the result for 10 is very close to 19, but not necessarily 19.

As you work with neural networks, you'll see this pattern recurring. You will almost always deal with probabilities, not certainties, and will do a little bit of coding to figure out what the result is based on the probabilities, particularly when it comes to classification.