

# worksheet\_23

May 1, 2024

## 1 Worksheet 23

Name: honghao zhao UID: U44266035

### 1.0.1 Topics

- Tuning Neural Networks

### 1.1 Tuning Neural Networks

Nothing to do in this worksheet except follow along in lecture / use this code to better understand Neural Networks.

```
[1]: import math as m
import numpy as np
import matplotlib.pyplot as plt
import sklearn.datasets as datasets
from tensorflow import keras, math, random, stack
from tensorflow.keras import layers, initializers
from tensorflow.keras.activations import relu

# Set random seed for reproducibility
np.random.seed(1)
random.set_seed(1)

# Data generation - don't modify
centers = [[0, 0]]
t, _ = datasets.make_blobs(n_samples=200, centers=centers, cluster_std=1,
                           random_state=1)

colors = np.array([x for x in 'bgrcmk'])

# CURVE
def generate_curve_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : m.cos(4*x[0]) - x[1] < -.5 or m.
↪cos(4*x[0]) - x[1] > .5, t)))
    Y = np.array([1 if m.cos(4*x[0]) - x[1] >= 0 else 0 for x in X])
```

```

    return X, Y

# The model - modify this
model = keras.models.Sequential()
model.add(layers.Dense(3, input_dim=2, activation="sigmoid"))
model.add(layers.Dense(1, activation="sigmoid"))
model.compile(loss="binary_crossentropy")

X, Y = generate_curve_data(t)

# plot the data
plt.scatter(X[:,0],X[:,1],color=colors[Y].tolist(), s=100, alpha=.9)
plt.show()

history = model.fit(X, Y, batch_size=50, epochs=200)

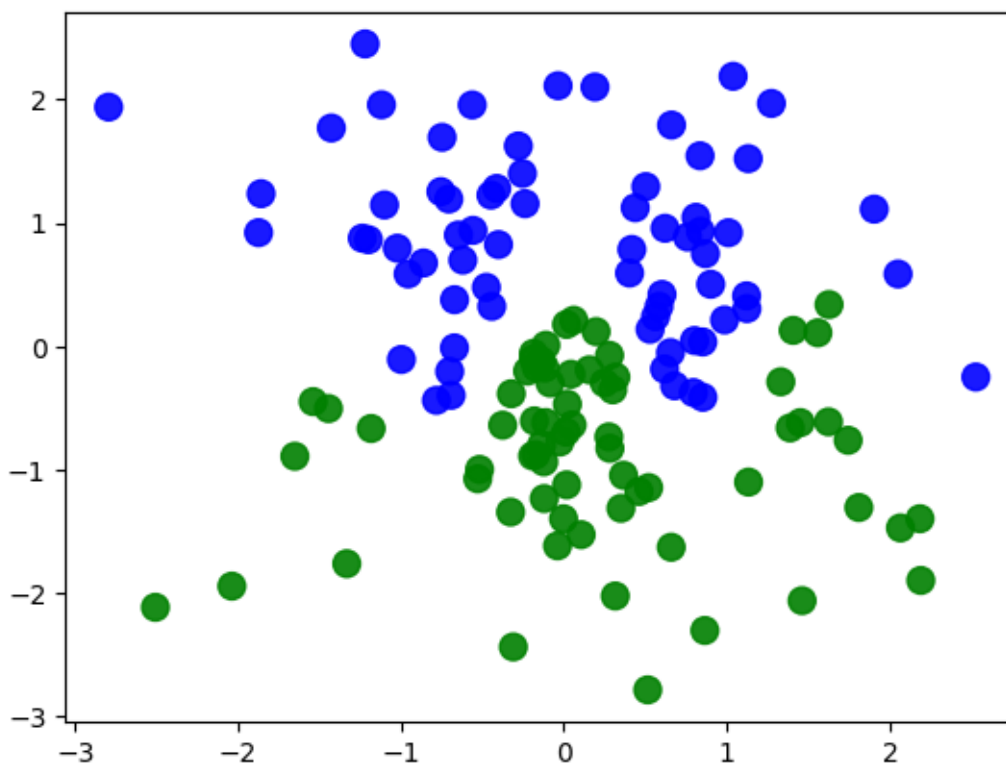
# Plot the decision boundary

# create a mesh to plot in
h = .02 # step size in the mesh
x_min, x_max = X[:, 0].min() - .5, X[:, 0].max() + 1
y_min, y_max = X[:, 1].min() - .5, X[:, 1].max() + 1
xx, yy = np.meshgrid(np.arange(x_min, x_max, h),
                     np.arange(y_min, y_max, h))
meshData = np.c_[xx.ravel(), yy.ravel()]

fig, ax = plt.subplots()
Z = model.predict(meshData)
Z = np.array([0 if x < .5 else 1 for x in Z])
Z = Z.reshape(xx.shape)
ax.contourf(xx, yy, Z, alpha=.3, cmap=plt.cm.Paired)
ax.axis('off')

# Plot also the training points
ax.scatter(X[:, 0], X[:, 1], color=colors[Y].tolist(), s=100, alpha=.9)
plt.title("Decision Boundary")
plt.show()

```



```
Epoch 1/200
3/3 [=====] - 2s 19ms/step - loss: 0.6523
Epoch 2/200
3/3 [=====] - 0s 12ms/step - loss: 0.6506
Epoch 3/200
3/3 [=====] - 0s 12ms/step - loss: 0.6494
Epoch 4/200
3/3 [=====] - 0s 10ms/step - loss: 0.6485
Epoch 5/200
3/3 [=====] - 0s 8ms/step - loss: 0.6476
Epoch 6/200
3/3 [=====] - 0s 18ms/step - loss: 0.6468
Epoch 7/200
3/3 [=====] - 0s 12ms/step - loss: 0.6461
Epoch 8/200
3/3 [=====] - 0s 9ms/step - loss: 0.6453
Epoch 9/200
3/3 [=====] - 0s 12ms/step - loss: 0.6446
Epoch 10/200
3/3 [=====] - 0s 7ms/step - loss: 0.6439
Epoch 11/200
3/3 [=====] - 0s 8ms/step - loss: 0.6432
```

Epoch 12/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6426  
Epoch 13/200  
3/3 [=====] - 0s 32ms/step - loss: 0.6419  
Epoch 14/200  
3/3 [=====] - 0s 19ms/step - loss: 0.6412  
Epoch 15/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6406  
Epoch 16/200  
3/3 [=====] - 0s 15ms/step - loss: 0.6398  
Epoch 17/200  
3/3 [=====] - 0s 16ms/step - loss: 0.6392  
Epoch 18/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6386  
Epoch 19/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6379  
Epoch 20/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6373  
Epoch 21/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6366  
Epoch 22/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6360  
Epoch 23/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6353  
Epoch 24/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6348  
Epoch 25/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6340  
Epoch 26/200  
3/3 [=====] - 0s 10ms/step - loss: 0.6333  
Epoch 27/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6327  
Epoch 28/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6320  
Epoch 29/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6314  
Epoch 30/200  
3/3 [=====] - 0s 42ms/step - loss: 0.6307  
Epoch 31/200  
3/3 [=====] - 0s 11ms/step - loss: 0.6300  
Epoch 32/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6294  
Epoch 33/200  
3/3 [=====] - 0s 12ms/step - loss: 0.6287  
Epoch 34/200  
3/3 [=====] - 0s 25ms/step - loss: 0.6280  
Epoch 35/200  
3/3 [=====] - 0s 14ms/step - loss: 0.6273

Epoch 36/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6267  
Epoch 37/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6260  
Epoch 38/200  
3/3 [=====] - 0s 14ms/step - loss: 0.6253  
Epoch 39/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6247  
Epoch 40/200  
3/3 [=====] - 0s 14ms/step - loss: 0.6240  
Epoch 41/200  
3/3 [=====] - 0s 11ms/step - loss: 0.6233  
Epoch 42/200  
3/3 [=====] - 0s 30ms/step - loss: 0.6226  
Epoch 43/200  
3/3 [=====] - 0s 29ms/step - loss: 0.6219  
Epoch 44/200  
3/3 [=====] - 0s 19ms/step - loss: 0.6213  
Epoch 45/200  
3/3 [=====] - 0s 11ms/step - loss: 0.6206  
Epoch 46/200  
3/3 [=====] - 0s 11ms/step - loss: 0.6200  
Epoch 47/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6193  
Epoch 48/200  
3/3 [=====] - 0s 15ms/step - loss: 0.6187  
Epoch 49/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6180  
Epoch 50/200  
3/3 [=====] - 0s 10ms/step - loss: 0.6173  
Epoch 51/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6167  
Epoch 52/200  
3/3 [=====] - 0s 18ms/step - loss: 0.6161  
Epoch 53/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6155  
Epoch 54/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6148  
Epoch 55/200  
3/3 [=====] - 0s 10ms/step - loss: 0.6142  
Epoch 56/200  
3/3 [=====] - 0s 7ms/step - loss: 0.6135  
Epoch 57/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6128  
Epoch 58/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6123  
Epoch 59/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6116

Epoch 60/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6109  
Epoch 61/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6104  
Epoch 62/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6097  
Epoch 63/200  
3/3 [=====] - 0s 15ms/step - loss: 0.6092  
Epoch 64/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6085  
Epoch 65/200  
3/3 [=====] - 0s 7ms/step - loss: 0.6079  
Epoch 66/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6073  
Epoch 67/200  
3/3 [=====] - 0s 7ms/step - loss: 0.6067  
Epoch 68/200  
3/3 [=====] - 0s 5ms/step - loss: 0.6060  
Epoch 69/200  
3/3 [=====] - 0s 13ms/step - loss: 0.6054  
Epoch 70/200  
3/3 [=====] - 0s 9ms/step - loss: 0.6047  
Epoch 71/200  
3/3 [=====] - 0s 8ms/step - loss: 0.6042  
Epoch 72/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6035  
Epoch 73/200  
3/3 [=====] - 0s 5ms/step - loss: 0.6028  
Epoch 74/200  
3/3 [=====] - 0s 5ms/step - loss: 0.6022  
Epoch 75/200  
3/3 [=====] - 0s 7ms/step - loss: 0.6015  
Epoch 76/200  
3/3 [=====] - 0s 6ms/step - loss: 0.6009  
Epoch 77/200  
3/3 [=====] - 0s 5ms/step - loss: 0.6002  
Epoch 78/200  
3/3 [=====] - 0s 6ms/step - loss: 0.5996  
Epoch 79/200  
3/3 [=====] - 0s 6ms/step - loss: 0.5990  
Epoch 80/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5984  
Epoch 81/200  
3/3 [=====] - 0s 5ms/step - loss: 0.5977  
Epoch 82/200  
3/3 [=====] - 0s 14ms/step - loss: 0.5971  
Epoch 83/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5964

Epoch 84/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5957  
Epoch 85/200  
3/3 [=====] - 0s 14ms/step - loss: 0.5951  
Epoch 86/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5944  
Epoch 87/200  
3/3 [=====] - 0s 15ms/step - loss: 0.5938  
Epoch 88/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5931  
Epoch 89/200  
3/3 [=====] - 0s 7ms/step - loss: 0.5924  
Epoch 90/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5918  
Epoch 91/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5911  
Epoch 92/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5905  
Epoch 93/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5898  
Epoch 94/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5892  
Epoch 95/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5886  
Epoch 96/200  
3/3 [=====] - 0s 31ms/step - loss: 0.5879  
Epoch 97/200  
3/3 [=====] - 0s 20ms/step - loss: 0.5873  
Epoch 98/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5867  
Epoch 99/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5860  
Epoch 100/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5855  
Epoch 101/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5848  
Epoch 102/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5842  
Epoch 103/200  
3/3 [=====] - 0s 19ms/step - loss: 0.5835  
Epoch 104/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5829  
Epoch 105/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5823  
Epoch 106/200  
3/3 [=====] - 0s 23ms/step - loss: 0.5817  
Epoch 107/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5810

Epoch 108/200  
3/3 [=====] - 0s 16ms/step - loss: 0.5803  
Epoch 109/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5797  
Epoch 110/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5790  
Epoch 111/200  
3/3 [=====] - 0s 13ms/step - loss: 0.5783  
Epoch 112/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5777  
Epoch 113/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5771  
Epoch 114/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5764  
Epoch 115/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5757  
Epoch 116/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5751  
Epoch 117/200  
3/3 [=====] - 0s 4ms/step - loss: 0.5744  
Epoch 118/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5737  
Epoch 119/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5731  
Epoch 120/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5725  
Epoch 121/200  
3/3 [=====] - 0s 13ms/step - loss: 0.5718  
Epoch 122/200  
3/3 [=====] - 0s 16ms/step - loss: 0.5711  
Epoch 123/200  
3/3 [=====] - 0s 14ms/step - loss: 0.5705  
Epoch 124/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5699  
Epoch 125/200  
3/3 [=====] - 0s 18ms/step - loss: 0.5692  
Epoch 126/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5685  
Epoch 127/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5679  
Epoch 128/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5671  
Epoch 129/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5664  
Epoch 130/200  
3/3 [=====] - 0s 5ms/step - loss: 0.5658  
Epoch 131/200  
3/3 [=====] - 0s 18ms/step - loss: 0.5650

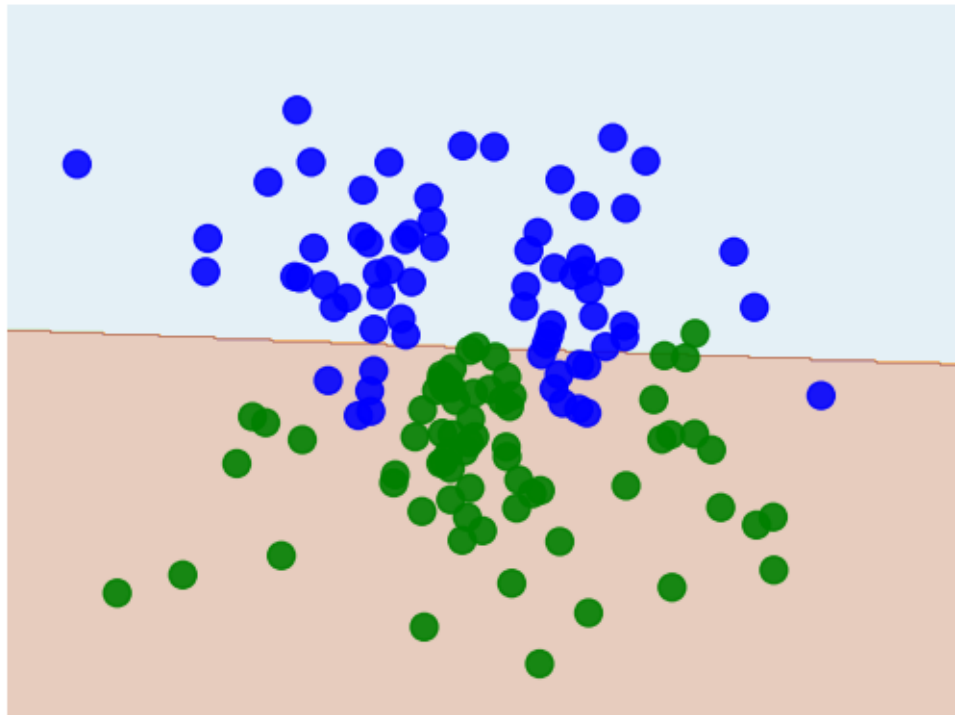


Epoch 132/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5644  
Epoch 133/200  
3/3 [=====] - 0s 19ms/step - loss: 0.5637  
Epoch 134/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5630  
Epoch 135/200  
3/3 [=====] - 0s 29ms/step - loss: 0.5623  
Epoch 136/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5616  
Epoch 137/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5608  
Epoch 138/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5602  
Epoch 139/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5594  
Epoch 140/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5588  
Epoch 141/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5582  
Epoch 142/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5573  
Epoch 143/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5567  
Epoch 144/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5560  
Epoch 145/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5554  
Epoch 146/200  
3/3 [=====] - 0s 6ms/step - loss: 0.5547  
Epoch 147/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5540  
Epoch 148/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5533  
Epoch 149/200  
3/3 [=====] - 0s 6ms/step - loss: 0.5527  
Epoch 150/200  
3/3 [=====] - 0s 16ms/step - loss: 0.5520  
Epoch 151/200  
3/3 [=====] - 0s 7ms/step - loss: 0.5512  
Epoch 152/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5506  
Epoch 153/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5499  
Epoch 154/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5491  
Epoch 155/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5484

Epoch 156/200  
3/3 [=====] - 0s 7ms/step - loss: 0.5477  
Epoch 157/200  
3/3 [=====] - 0s 16ms/step - loss: 0.5470  
Epoch 158/200  
3/3 [=====] - 0s 17ms/step - loss: 0.5462  
Epoch 159/200  
3/3 [=====] - 0s 13ms/step - loss: 0.5455  
Epoch 160/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5449  
Epoch 161/200  
3/3 [=====] - 0s 17ms/step - loss: 0.5441  
Epoch 162/200  
3/3 [=====] - 0s 14ms/step - loss: 0.5435  
Epoch 163/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5427  
Epoch 164/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5421  
Epoch 165/200  
3/3 [=====] - 0s 12ms/step - loss: 0.5414  
Epoch 166/200  
3/3 [=====] - 0s 16ms/step - loss: 0.5407  
Epoch 167/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5400  
Epoch 168/200  
3/3 [=====] - 0s 24ms/step - loss: 0.5393  
Epoch 169/200  
3/3 [=====] - 0s 9ms/step - loss: 0.5386  
Epoch 170/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5380  
Epoch 171/200  
3/3 [=====] - 0s 7ms/step - loss: 0.5373  
Epoch 172/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5367  
Epoch 173/200  
3/3 [=====] - 0s 14ms/step - loss: 0.5359  
Epoch 174/200  
3/3 [=====] - 0s 20ms/step - loss: 0.5352  
Epoch 175/200  
3/3 [=====] - 0s 11ms/step - loss: 0.5345  
Epoch 176/200  
3/3 [=====] - 0s 8ms/step - loss: 0.5338  
Epoch 177/200  
3/3 [=====] - 0s 10ms/step - loss: 0.5331  
Epoch 178/200  
3/3 [=====] - 0s 18ms/step - loss: 0.5324  
Epoch 179/200  
3/3 [=====] - 0s 6ms/step - loss: 0.5316

Epoch 180/200  
 3/3 [=====] - 0s 15ms/step - loss: 0.5309  
 Epoch 181/200  
 3/3 [=====] - 0s 19ms/step - loss: 0.5302  
 Epoch 182/200  
 3/3 [=====] - 0s 16ms/step - loss: 0.5295  
 Epoch 183/200  
 3/3 [=====] - 0s 14ms/step - loss: 0.5287  
 Epoch 184/200  
 3/3 [=====] - 0s 14ms/step - loss: 0.5281  
 Epoch 185/200  
 3/3 [=====] - 0s 22ms/step - loss: 0.5273  
 Epoch 186/200  
 3/3 [=====] - 0s 29ms/step - loss: 0.5266  
 Epoch 187/200  
 3/3 [=====] - 0s 22ms/step - loss: 0.5259  
 Epoch 188/200  
 3/3 [=====] - 0s 8ms/step - loss: 0.5252  
 Epoch 189/200  
 3/3 [=====] - 0s 12ms/step - loss: 0.5244  
 Epoch 190/200  
 3/3 [=====] - 0s 16ms/step - loss: 0.5237  
 Epoch 191/200  
 3/3 [=====] - 0s 7ms/step - loss: 0.5230  
 Epoch 192/200  
 3/3 [=====] - 0s 10ms/step - loss: 0.5223  
 Epoch 193/200  
 3/3 [=====] - 0s 20ms/step - loss: 0.5215  
 Epoch 194/200  
 3/3 [=====] - 0s 14ms/step - loss: 0.5208  
 Epoch 195/200  
 3/3 [=====] - 0s 10ms/step - loss: 0.5201  
 Epoch 196/200  
 3/3 [=====] - 0s 9ms/step - loss: 0.5194  
 Epoch 197/200  
 3/3 [=====] - 0s 7ms/step - loss: 0.5187  
 Epoch 198/200  
 3/3 [=====] - 0s 8ms/step - loss: 0.5180  
 Epoch 199/200  
 3/3 [=====] - 0s 18ms/step - loss: 0.5173  
 Epoch 200/200  
 3/3 [=====] - 0s 8ms/step - loss: 0.5166  
 3602/3602 [=====] - 10s 3ms/step

Decision Boundary



[ ]: