worksheet_22

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1 Worksheet 22

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1.0.1 Topics

- Neural Networks

1.1 Neural Networks

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

[2]:
```
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

#       x[0] --- h1
#            \ /   \
#             X      output
#            / \   /
#       x[1] --- h2
#
# This is the base model - nothing fancy here

# 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 'bgrcmyk'])
colors = np.hstack([colors] * 20)

# CIRCLE
def generate_circle_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : (x[0] - centers[0][0])**2 + (x[1] -␣
 ↪centers[0][1])**2 < 1 or (x[0] - centers[0][0])**2 + (x[1] -␣
 ↪centers[0][1])**2 > 1.5, t)))
    Y = np.array([1 if (x[0] - centers[0][0])**2 + (x[1] - centers[0][1])**2 >=␣
 ↪1 else 0 for x in X])
    return X, Y

# LINE
def generate_line_data(t):
    # create some space between the classes
    X = np.array(list(filter(lambda x : x[0] - x[1] < -.5 or x[0] - x[1] > .5,␣
 ↪t)))
    Y = np.array([1 if x[0] - x[1] >= 0 else 0 for x in X])
    return X, Y

# 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

# XOR
def generate_xor_data():
    X = np.array([
        [0,0],
        [0,1],
        [1,0],
        [1,1]])
    Y = np.array([x[0]^x[1] for x in X])
    return X, Y

PLOT_HIDDEN_LAYER_2D = False
PLOT_HIDDEN_LAYER_3D = True

# 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_circle_data(t)
# X, Y = generate_line_data(t)
# X, Y = generate_curve_data(t)
X, Y = generate_xor_data()

# 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=1, epochs=1000)

if PLOT_HIDDEN_LAYER_2D:
    # Show the transformation of the input at the first hidden layer
    layer = model.layers[0]
    print(layer.get_config(), layer.get_weights())
    keras_function = keras.backend.function([model.input], [layer.output])
    layerVals = np.array(keras_function(X))[0]
    plt.scatter(layerVals[:,0], layerVals[:, 1], color=colors[Y].tolist(),␣
 ↪s=100, alpha=.9)
    plt.show()

    # create a mesh to plot in
    h = .02  # step size in the mesh
    x_min, x_max = layerVals[:, 0].min() - .5, layerVals[:, 0].max() + 1
    y_min, y_max = layerVals[:, 1].min() - .5, layerVals[:, 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()]

    # Plot the decision boundary. For that, we will assign a color to each
    # point in the mesh
    fig, ax = plt.subplots()
    layer = model.layers[-1]

    intermediateModel = keras.models.Sequential()
    intermediateModel.add(layers.Dense(1, input_dim=2, activation="sigmoid"))
    intermediateModel.compile(loss="binary_crossentropy")
    intermediateModel.layers[0].set_weights(layer.get_weights())

    Z = intermediateModel.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)

    T = intermediateModel.predict(layerVals)
    T = np.array([0 if x < .5 else 1 for x in T])
```

```
    T = T.reshape(layerVals[:, 0].shape)
    ax.scatter(layerVals[:, 0], layerVals[:, 1], color=colors[T].tolist(),␣
 ↪s=100, alpha=.9)
    ax.set_xlabel("h0")
    ax.set_ylabel("h1")
    plt.show()

if PLOT_HIDDEN_LAYER_3D:
    # Show the transformation of the input at the first hidden layer
    layer = model.layers[0]
    print(layer.get_config(), layer.get_weights())
    keras_function = keras.backend.function([model.input], [layer.output])
    layerVals = np.array(keras_function(X))[0]
    fig = plt.figure()
    ax = fig.add_subplot(111, projection='3d')
    ax.scatter(layerVals[:,0], layerVals[:, 1], layerVals[:, 2],␣
 ↪color=colors[Y].tolist(), s=100, alpha=.9)
    plt.show()

    # create a mesh to plot in
    h = .1  # step size in the mesh
    x_min, x_max = layerVals[:, 0].min() - .5, layerVals[:, 0].max() + 1
    y_min, y_max = layerVals[:, 1].min() - .5, layerVals[:, 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(), np.zeros(len(xx.ravel()))]

    # Plot the decision boundary. For that, we will assign a color to each
    # point in the mesh
    fig, ax = plt.subplots()
    layer = model.layers[-1]

    intermediateModel = keras.models.Sequential()
    intermediateModel.add(layers.Dense(1, input_dim=3, activation="sigmoid"))
    intermediateModel.compile(loss="binary_crossentropy")
    intermediateModel.layers[0].set_weights(layer.get_weights())

    Z = intermediateModel.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) # plot in 2D
    ax.axis('off')

    T = intermediateModel.predict(layerVals)
    T = np.array([0 if x < .5 else 1 for x in T])
    T = T.reshape(layerVals[:, 0].shape)
```

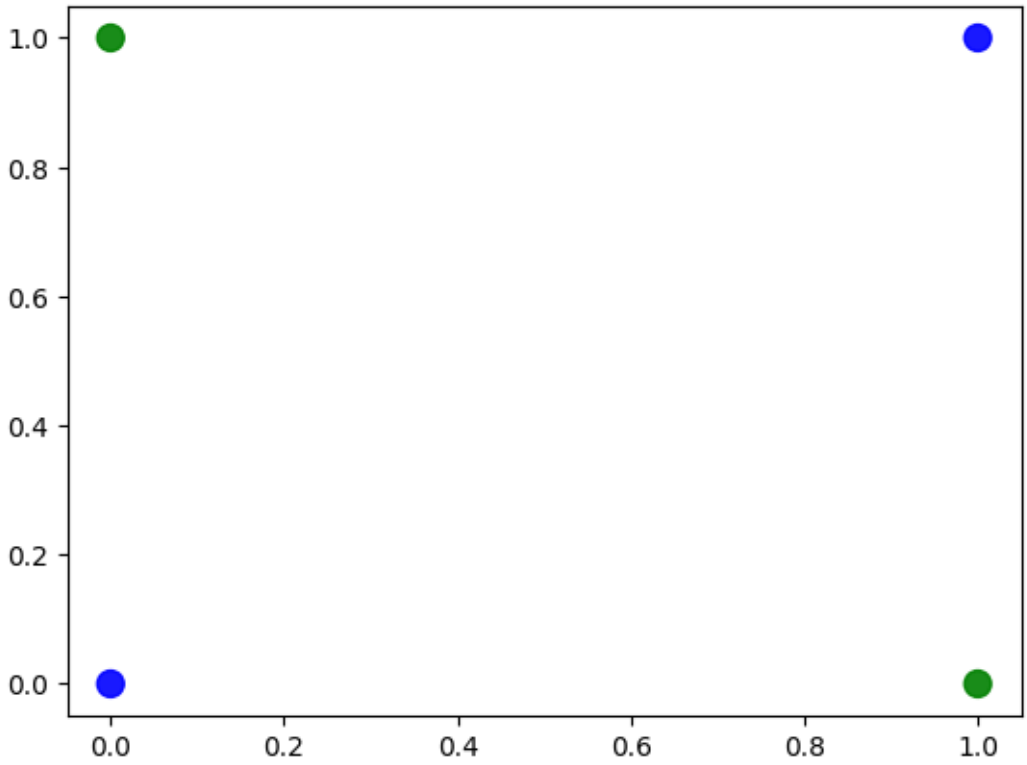
```
    ax.scatter(layerVals[:, 0], layerVals[:, 1], color=colors[T].tolist(),␣
 ↪s=100, alpha=.9) # plot in 2D
    plt.show()

# 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
T = model.predict(X)
T = np.array([0 if x < .5 else 1 for x in T])
T = T.reshape(X[:,0].shape)
ax.scatter(X[:, 0], X[:, 1], color=colors[T].tolist(), s=100, alpha=.9)
plt.title("Decision Boundary")
plt.show()
```




```
Epoch 1/1000
4/4 [==============================] - 1s 23ms/step - loss: 0.7117
Epoch 2/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7105
Epoch 3/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.7101
Epoch 4/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7098
Epoch 5/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7095
Epoch 6/1000
4/4 [==============================] - 0s 15ms/step - loss: 0.7093
Epoch 7/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7091
Epoch 8/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7090
Epoch 9/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7088
Epoch 10/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7086
Epoch 11/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7084
```

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Epoch 12/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7082
Epoch 13/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7081
Epoch 14/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7079
Epoch 15/1000
4/4 [==============================] - 0s 17ms/step - loss: 0.7077
Epoch 16/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7076
Epoch 17/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.7075
Epoch 18/1000
4/4 [==============================] - 0s 12ms/step - loss: 0.7073
Epoch 19/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.7071
Epoch 20/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7070
Epoch 21/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.7068
Epoch 22/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7067
Epoch 23/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7065
Epoch 24/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7064
Epoch 25/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7062
Epoch 26/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7061
Epoch 27/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7060
Epoch 28/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.7058
Epoch 29/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.7057
Epoch 30/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7056
Epoch 31/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7054
Epoch 32/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7053
Epoch 33/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7052
Epoch 34/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7051
Epoch 35/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7049
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Epoch 36/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7048
Epoch 37/1000
4/4 [==============================] - 0s 3ms/step - loss: 0.7046
Epoch 38/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7045
Epoch 39/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7044
Epoch 40/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7043
Epoch 41/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7041
Epoch 42/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.7040
Epoch 43/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7039
Epoch 44/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7038
Epoch 45/1000
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Epoch 46/1000
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Epoch 47/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7035
Epoch 48/1000
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Epoch 49/1000
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Epoch 50/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7031
Epoch 51/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7030
Epoch 52/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7029
Epoch 53/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7028
Epoch 54/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7027
Epoch 55/1000
4/4 [==============================] - 0s 16ms/step - loss: 0.7026
Epoch 56/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.7025
Epoch 57/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.7024
Epoch 58/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7023
Epoch 59/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7022
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Epoch 60/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.7021
Epoch 61/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7020
Epoch 62/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.7019
Epoch 63/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7018
Epoch 64/1000
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Epoch 65/1000
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Epoch 66/1000
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Epoch 67/1000
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Epoch 68/1000
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Epoch 69/1000
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Epoch 70/1000
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Epoch 71/1000
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Epoch 82/1000
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Epoch 83/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7002
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Epoch 84/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7001
Epoch 85/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7000
Epoch 86/1000
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Epoch 87/1000
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Epoch 88/1000
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Epoch 107/1000
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Epoch 108/1000
4/4 [==============================] - 0s 35ms/step - loss: 0.6986
Epoch 109/1000
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Epoch 132/1000
4/4 [==============================] - 0s 19ms/step - loss: 0.6974
Epoch 133/1000
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Epoch 134/1000
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Epoch 156/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6966
Epoch 157/1000
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Epoch 163/1000
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Epoch 166/1000
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Epoch 167/1000
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Epoch 168/1000
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Epoch 170/1000
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Epoch 171/1000
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Epoch 172/1000
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Epoch 173/1000
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Epoch 174/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6961
Epoch 175/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6960
Epoch 176/1000
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Epoch 177/1000
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Epoch 178/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6960
Epoch 179/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6959
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Epoch 180/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6959
Epoch 181/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6959
Epoch 182/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6959
Epoch 183/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6958
Epoch 184/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6958
Epoch 185/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6958
Epoch 186/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6958
Epoch 187/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6958
Epoch 188/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6957
Epoch 189/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6957
Epoch 190/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6957
Epoch 191/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6957
Epoch 192/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6957
Epoch 193/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6956
Epoch 194/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6956
Epoch 195/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6956
Epoch 196/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6956
Epoch 197/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6955
Epoch 198/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6955
Epoch 199/1000
4/4 [==============================] - 0s 14ms/step - loss: 0.6955
Epoch 200/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6955
Epoch 201/1000
4/4 [==============================] - 0s 18ms/step - loss: 0.6954
Epoch 202/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6954
Epoch 203/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6954
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Epoch 204/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6954
Epoch 205/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6954
Epoch 206/1000
4/4 [==============================] - 0s 24ms/step - loss: 0.6953
Epoch 207/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6953
Epoch 208/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6953
Epoch 209/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6953
Epoch 210/1000
4/4 [==============================] - 0s 16ms/step - loss: 0.6953
Epoch 211/1000
4/4 [==============================] - 0s 14ms/step - loss: 0.6953
Epoch 212/1000
4/4 [==============================] - 0s 12ms/step - loss: 0.6953
Epoch 213/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6952
Epoch 214/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6952
Epoch 215/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6952
Epoch 216/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6952
Epoch 217/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6952
Epoch 218/1000
4/4 [==============================] - 0s 22ms/step - loss: 0.6952
Epoch 219/1000
4/4 [==============================] - 0s 13ms/step - loss: 0.6951
Epoch 220/1000
4/4 [==============================] - 0s 12ms/step - loss: 0.6951
Epoch 221/1000
4/4 [==============================] - 0s 18ms/step - loss: 0.6951
Epoch 222/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6951
Epoch 223/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6951
Epoch 224/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6951
Epoch 225/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6950
Epoch 226/1000
4/4 [==============================] - 0s 16ms/step - loss: 0.6950
Epoch 227/1000
4/4 [==============================] - 0s 14ms/step - loss: 0.6950
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Epoch 228/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6950
Epoch 229/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6950
Epoch 230/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6950
Epoch 231/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6950
Epoch 232/1000
4/4 [==============================] - 0s 16ms/step - loss: 0.6950
Epoch 233/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6949
Epoch 234/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6949
Epoch 235/1000
4/4 [==============================] - 0s 12ms/step - loss: 0.6949
Epoch 236/1000
4/4 [==============================] - 0s 12ms/step - loss: 0.6949
Epoch 237/1000
4/4 [==============================] - 0s 19ms/step - loss: 0.6949
Epoch 238/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6949
Epoch 239/1000
4/4 [==============================] - 0s 13ms/step - loss: 0.6949
Epoch 240/1000
4/4 [==============================] - 0s 13ms/step - loss: 0.6949
Epoch 241/1000
4/4 [==============================] - 0s 14ms/step - loss: 0.6948
Epoch 242/1000
4/4 [==============================] - 0s 17ms/step - loss: 0.6948
Epoch 243/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6948
Epoch 244/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6948
Epoch 245/1000
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Epoch 246/1000
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Epoch 247/1000
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Epoch 248/1000
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Epoch 249/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6948
Epoch 250/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6948
Epoch 251/1000
4/4 [==============================] - 0s 9ms/step - loss: 0.6947
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Epoch 252/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6947
Epoch 253/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6947
Epoch 254/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6947
Epoch 255/1000
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Epoch 256/1000
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Epoch 257/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6947
Epoch 258/1000
4/4 [==============================] - 0s 10ms/step - loss: 0.6947
Epoch 259/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6947
Epoch 260/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6946
Epoch 261/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6946
Epoch 262/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6946
Epoch 263/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6946
Epoch 264/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6946
Epoch 265/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6946
Epoch 266/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6946
Epoch 267/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6946
Epoch 268/1000
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Epoch 269/1000
4/4 [==============================] - 0s 11ms/step - loss: 0.6946
Epoch 270/1000
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Epoch 271/1000
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Epoch 272/1000
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Epoch 273/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6945
Epoch 274/1000
4/4 [==============================] - 0s 19ms/step - loss: 0.6945
Epoch 275/1000
4/4 [==============================] - 0s 20ms/step - loss: 0.6945
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Epoch 276/1000
4/4 [==============================] - 0s 24ms/step - loss: 0.6945
Epoch 277/1000
4/4 [==============================] - 0s 29ms/step - loss: 0.6945
Epoch 278/1000
4/4 [==============================] - 0s 16ms/step - loss: 0.6945
Epoch 279/1000
4/4 [==============================] - 0s 19ms/step - loss: 0.6945
Epoch 280/1000
4/4 [==============================] - 0s 13ms/step - loss: 0.6945
Epoch 281/1000
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Epoch 283/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6945
Epoch 284/1000
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Epoch 285/1000
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Epoch 286/1000
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Epoch 299/1000
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Epoch 300/1000
4/4 [==============================] - 0s 3ms/step - loss: 0.6943
Epoch 301/1000
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Epoch 323/1000
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Epoch 324/1000
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Epoch 348/1000
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Epoch 371/1000
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Epoch 372/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6940
Epoch 373/1000
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Epoch 395/1000
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Epoch 396/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6939
Epoch 397/1000
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Epoch 420/1000
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Epoch 442/1000
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Epoch 443/1000
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Epoch 444/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6938
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Epoch 732/1000
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Epoch 996/1000
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Epoch 1000/1000
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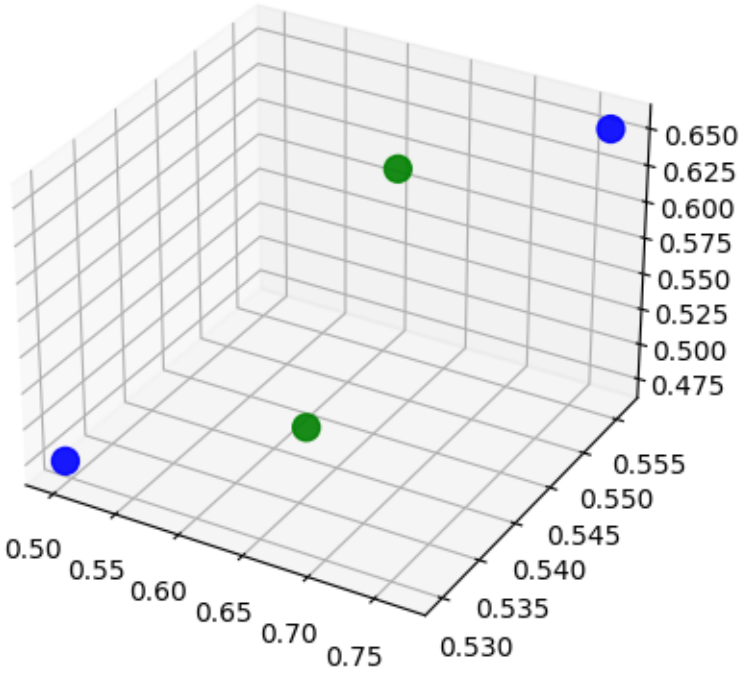
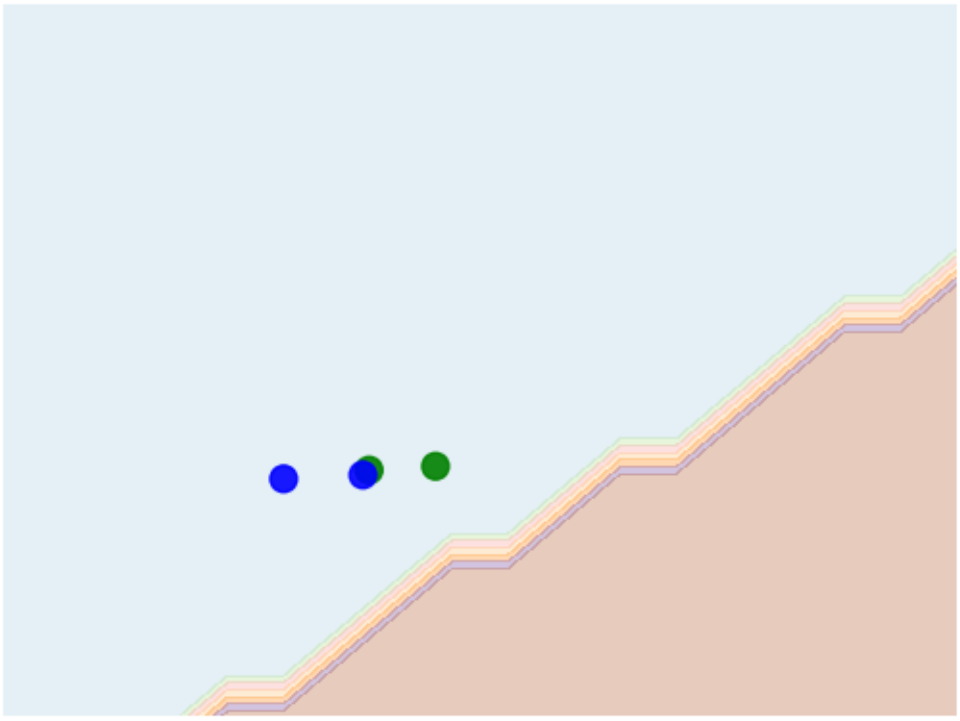
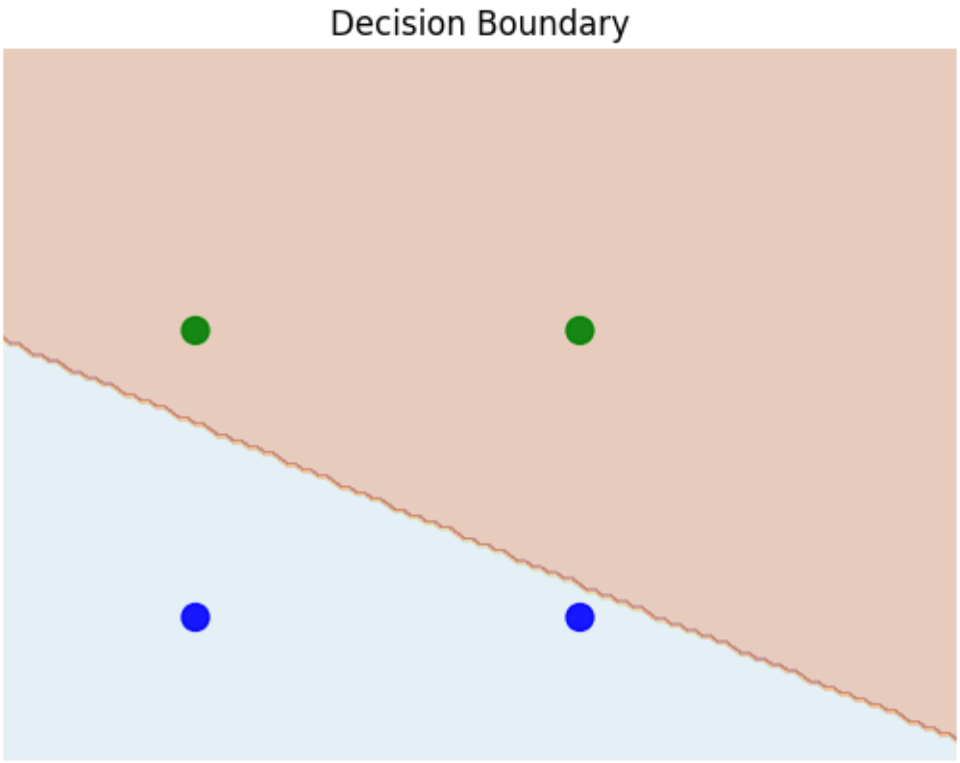
{'name': 'dense_2', 'trainable': True, 'dtype': 'float32', 'batch_input_shape':
(None, 2), 'units': 3, 'activation': 'sigmoid', 'use_bias': True,
'kernel_initializer': {'module': 'keras.initializers', 'class_name':
'GlorotUniform', 'config': {'seed': None}, 'registered_name': None},
'bias_initializer': {'module': 'keras.initializers', 'class_name': 'Zeros',
'config': {}, 'registered_name': None}, 'kernel_regularizer': None,
'bias_regularizer': None, 'activity_regularizer': None, 'kernel_constraint':
None, 'bias_constraint': None} [array([[0.58010656, 0.03286194, 0.09190112],
       [0.62845725, 0.07436391, 0.64381844]], dtype=float32),
array([-0.01044651,  0.11893862, -0.10347107], dtype=float32)]
```




```
9/9 [==============================] - 0s 3ms/step
1/1 [==============================] - 0s 75ms/step
```



```
489/489 [==============================] - 1s 2ms/step
1/1 [==============================] - 0s 61ms/step
```


Decision Boundary

[ ]: