Worksheet 22

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Topics

- Neural Networks

Neural Networks

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

In [15]:
```
pip install tensorflow
```

```
Requirement already satisfied: tensorflow in /usr/local/lib/python3.10/dist-p
ackages (2.15.0)
Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.10/di
st-packages (from tensorflow) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.1
0/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in /usr/local/lib/python
3.10/dist-packages (from tensorflow) (24.3.25)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in /usr/lo
cal/lib/python3.10/dist-packages (from tensorflow) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in /usr/local/lib/python3.
10/dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: h5py>=2.9.0 in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (3.9.0)
Requirement already satisfied: libclang>=13.0.0 in /usr/local/lib/python3.10/
dist-packages (from tensorflow) (18.1.1)
Requirement already satisfied: ml-dtypes~=0.2.0 in /usr/local/lib/python3.10/
dist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: numpy<2.0.0,>=1.23.5 in /usr/local/lib/python
3.10/dist-packages (from tensorflow) (1.25.2)
Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3.1
0/dist-packages (from tensorflow) (3.3.0)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-pa
ckages (from tensorflow) (24.0)
Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=
4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3 in /usr/local/lib/python3.10/dist-packages
(from tensorflow) (3.20.3)
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-p
ackages (from tensorflow) (67.7.2)
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.10/dist-
packages (from tensorflow) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.10/
dist-packages (from tensorflow) (2.4.0)
Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/pyt
hon3.10/dist-packages (from tensorflow) (4.11.0)
Requirement already satisfied: wrapt<1.15,>=1.11.0 in /usr/local/lib/python3.
10/dist-packages (from tensorflow) (1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in /usr/l
ocal/lib/python3.10/dist-packages (from tensorflow) (0.36.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.
10/dist-packages (from tensorflow) (1.62.2)
Requirement already satisfied: tensorboard<2.16,>=2.15 in /usr/local/lib/pyth
on3.10/dist-packages (from tensorflow) (2.15.2)
Requirement already satisfied: tensorflow-estimator<2.16,>=2.15.0 in /usr/loc
al/lib/python3.10/dist-packages (from tensorflow) (2.15.0)
Requirement already satisfied: keras<2.16,>=2.15.0 in /usr/local/lib/python3.
10/dist-packages (from tensorflow) (2.15.0)
Requirement already satisfied: wheel<1.0,>=0.23.0 in /usr/local/lib/python3.1
0/dist-packages (from astunparse>=1.6.0->tensorflow) (0.43.0)
Requirement already satisfied: google-auth<3,>=1.6.3 in /usr/local/lib/python
3.10/dist-packages (from tensorboard<2.16,>=2.15->tensorflow) (2.27.0)
Requirement already satisfied: google-auth-oauthlib<2,>=0.5 in /usr/local/li
b/python3.10/dist-packages (from tensorboard<2.16,>=2.15->tensorflow) (1.2.0)
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.10/d
ist-packages (from tensorboard<2.16,>=2.15->tensorflow) (3.6)
Requirement already satisfied: requests<3,>=2.21.0 in /usr/local/lib/python3.
```

```
10/dist-packages (from tensorboard<2.16,>=2.15->tensorflow) (2.31.0)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in /usr/
local/lib/python3.10/dist-packages (from tensorboard<2.16,>=2.15->tensorflow)
(0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in /usr/local/lib/python3.10/d
ist-packages (from tensorboard<2.16,>=2.15->tensorflow) (3.0.2)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in /usr/local/lib/pytho
n3.10/dist-packages (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->ten
sorflow) (5.3.3)
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python
3.10/dist-packages (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tens
orflow) (0.4.0)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.10/dis
t-packages (from google-auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow)
(4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/pyt
hon3.10/dist-packages (from google-auth-oauthlib<2,>=0.5->tensorboard<2.16,>=
2.15->tensorflow) (1.3.1)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/pyt
hon3.10/dist-packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->ten
sorflow) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist
-packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow) (3.
7)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.1
0/dist-packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflo
w) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.1
0/dist-packages (from requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflo
w) (2024.2.2)
Requirement already satisfied: MarkupSafe>=2.1.1 in /usr/local/lib/python3.1
0/dist-packages (from werkzeug>=1.0.1->tensorboard<2.16,>=2.15->tensorflow)
(2.1.5)
Requirement already satisfied: pyasn1<0.7.0,>=0.4.6 in /usr/local/lib/python
3.10/dist-packages (from pyasn1-modules>=0.2.1->google-auth<3,>=1.6.3->tensor
board<2.16,>=2.15->tensorflow) (0.6.0)
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.10/d
ist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib<2,>=0.5->te
nsorboard<2.16,>=2.15->tensorflow) (3.2.2)
```

In [31]:

```
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] -
    Y = np.array([1 if (x[0] - centers[0][0])**2 + (x[1] - centers[0][1])**2
    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] > .
    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(
    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 = True
PLOT_HIDDEN_LAYER_3D = False

# The model - modify this
model = keras.models.Sequential()
model.add(layers.Dense(2, 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
    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
    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=color
```

```
    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')

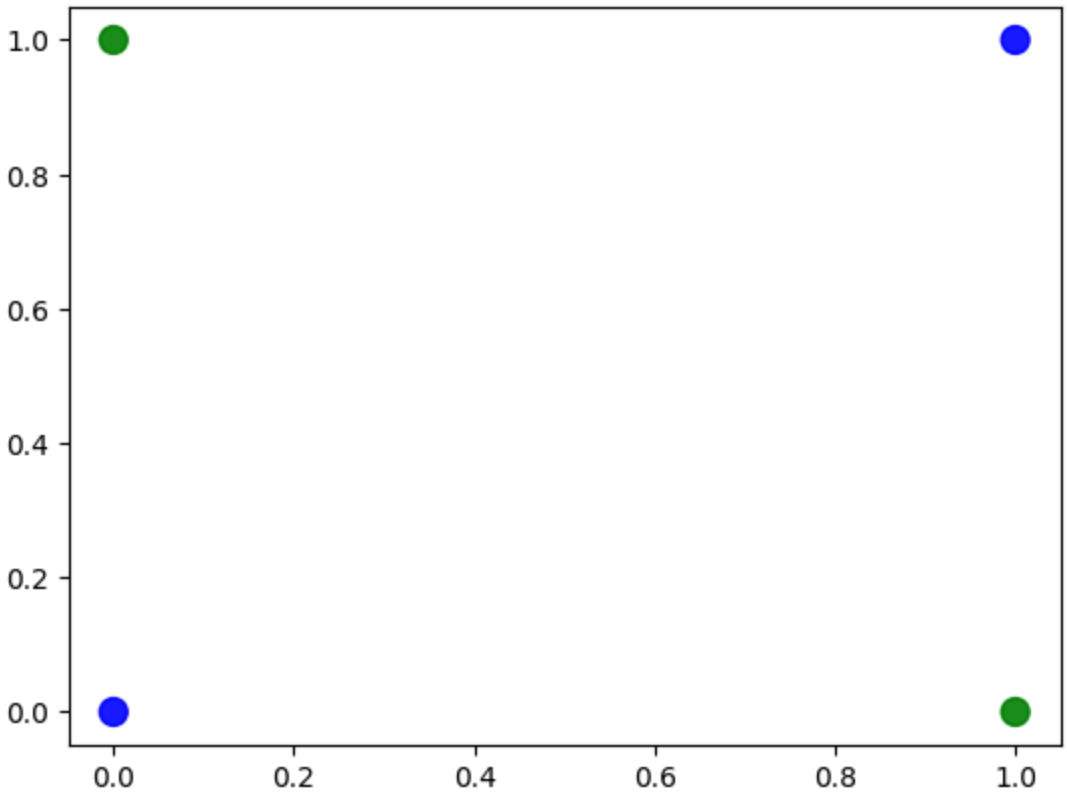
    T = intermediateModel.predict(layerVals)
    T = np.array([0 if x < .5 else 1 for x in T])
    T = T.reshape(layerVals[:, 0].shape)
    ax.scatter(layerVals[:, 0], layerVals[:, 1], color=colors[T].tolist(), s
    plt.show()

# 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()
```


1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

```
Epoch 1/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7269
Epoch 2/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7257
Epoch 3/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7253
Epoch 4/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7249
Epoch 5/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.7245
Epoch 6/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7243
Epoch 7/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7240
Epoch 8/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7237
Epoch 9/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7235
Epoch 10/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7232
Epoch 11/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7230
Epoch 12/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7227
Epoch 13/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7225
Epoch 14/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7222
Epoch 15/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7220
Epoch 16/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7218
Epoch 17/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7216
Epoch 18/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7213
Epoch 19/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7210
Epoch 20/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7208
Epoch 21/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7206
Epoch 22/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7204
Epoch 23/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7202
Epoch 24/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7200
Epoch 25/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7198
Epoch 26/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7195
Epoch 27/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7193
Epoch 28/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7191
```

```
Epoch 29/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7189
Epoch 30/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7187
Epoch 31/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7185
Epoch 32/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7183
Epoch 33/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7181
Epoch 34/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7179
Epoch 35/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7177
Epoch 36/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7175
Epoch 37/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7173
Epoch 38/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7171
Epoch 39/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7169
Epoch 40/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7167
Epoch 41/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7165
Epoch 42/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7163
Epoch 43/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7161
Epoch 44/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7160
Epoch 45/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7158
Epoch 46/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7156
Epoch 47/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7155
Epoch 48/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7152
Epoch 49/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7151
Epoch 50/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7149
Epoch 51/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7147
Epoch 52/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7146
Epoch 53/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7144
Epoch 54/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7143
Epoch 55/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7140
Epoch 56/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7139
```

```
Epoch 57/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7138
Epoch 58/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7136
Epoch 59/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7134
Epoch 60/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7132
Epoch 61/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7131
Epoch 62/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7130
Epoch 63/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7128
Epoch 64/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7126
Epoch 65/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7125
Epoch 66/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7123
Epoch 67/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7122
Epoch 68/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7121
Epoch 69/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7119
Epoch 70/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7117
Epoch 71/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7116
Epoch 72/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7115
Epoch 73/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7113
Epoch 74/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7112
Epoch 75/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7110
Epoch 76/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7109
Epoch 77/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7108
Epoch 78/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7106
Epoch 79/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7105
Epoch 80/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7104
Epoch 81/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7102
Epoch 82/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7101
Epoch 83/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7100
Epoch 84/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7099
```

```
Epoch 85/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7097
Epoch 86/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7096
Epoch 87/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7095
Epoch 88/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7093
Epoch 89/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7092
Epoch 90/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7091
Epoch 91/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7090
Epoch 92/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7088
Epoch 93/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.7088
Epoch 94/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7086
Epoch 95/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7085
Epoch 96/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.7084
Epoch 97/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7083
Epoch 98/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7082
Epoch 99/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7081
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Epoch 111/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7068
Epoch 112/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.7067
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4/4 [==============================] - 0s 4ms/step - loss: 0.7066
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Epoch 140/1000
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Epoch 196/1000
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Epoch 253/1000
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Epoch 925/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 926/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 927/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 928/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 929/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 930/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 931/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 932/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 933/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 934/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 935/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 936/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 937/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 938/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 939/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 940/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 941/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 942/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 943/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6944
Epoch 944/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6944
Epoch 945/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 946/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 947/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 948/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 949/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 950/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 951/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6944
Epoch 952/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
```

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Epoch 953/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6943
Epoch 954/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 955/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6944
Epoch 956/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 957/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 958/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6944
Epoch 959/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 960/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 961/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 962/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6943
Epoch 963/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 964/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 965/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 966/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 967/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 968/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 969/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 970/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 971/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 972/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 973/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6943
Epoch 974/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6943
Epoch 975/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 976/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 977/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 978/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 979/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 980/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
```

```
Epoch 981/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 982/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 983/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 984/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 985/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 986/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 987/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 988/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6943
Epoch 989/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 990/1000
4/4 [==============================] - 0s 7ms/step - loss: 0.6943
Epoch 991/1000
4/4 [==============================] - 0s 8ms/step - loss: 0.6943
Epoch 992/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 993/1000
4/4 [==============================] - 0s 4ms/step - loss: 0.6943
Epoch 994/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 995/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 996/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 997/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 998/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
Epoch 999/1000
4/4 [==============================] - 0s 5ms/step - loss: 0.6943
Epoch 1000/1000
4/4 [==============================] - 0s 6ms/step - loss: 0.6943
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m', 'config': {'seed': None}, 'registered_name': None}, 'bias_initializer':
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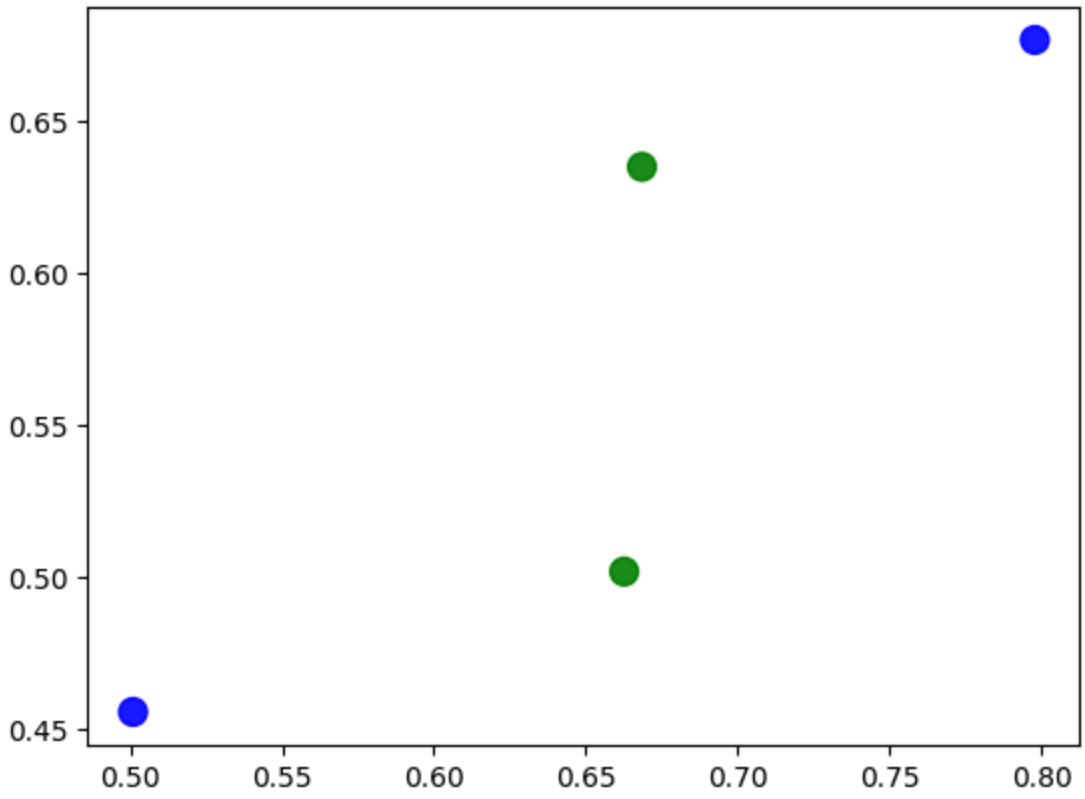
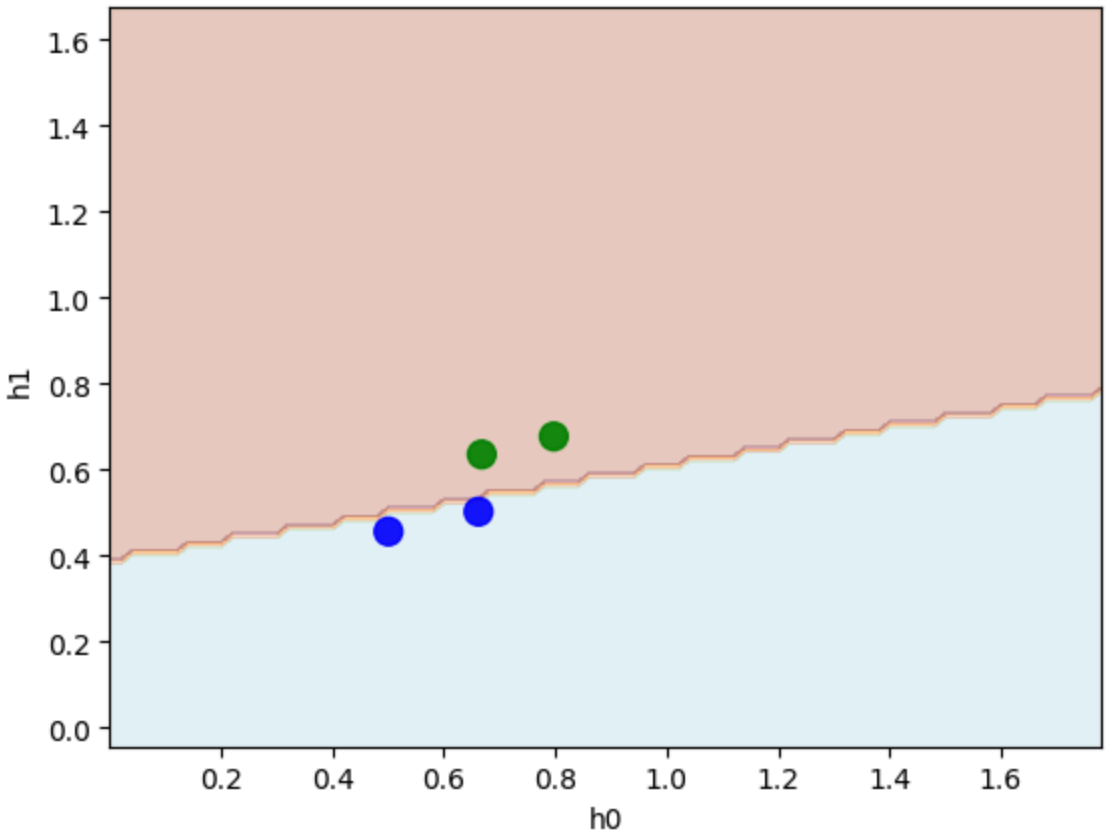
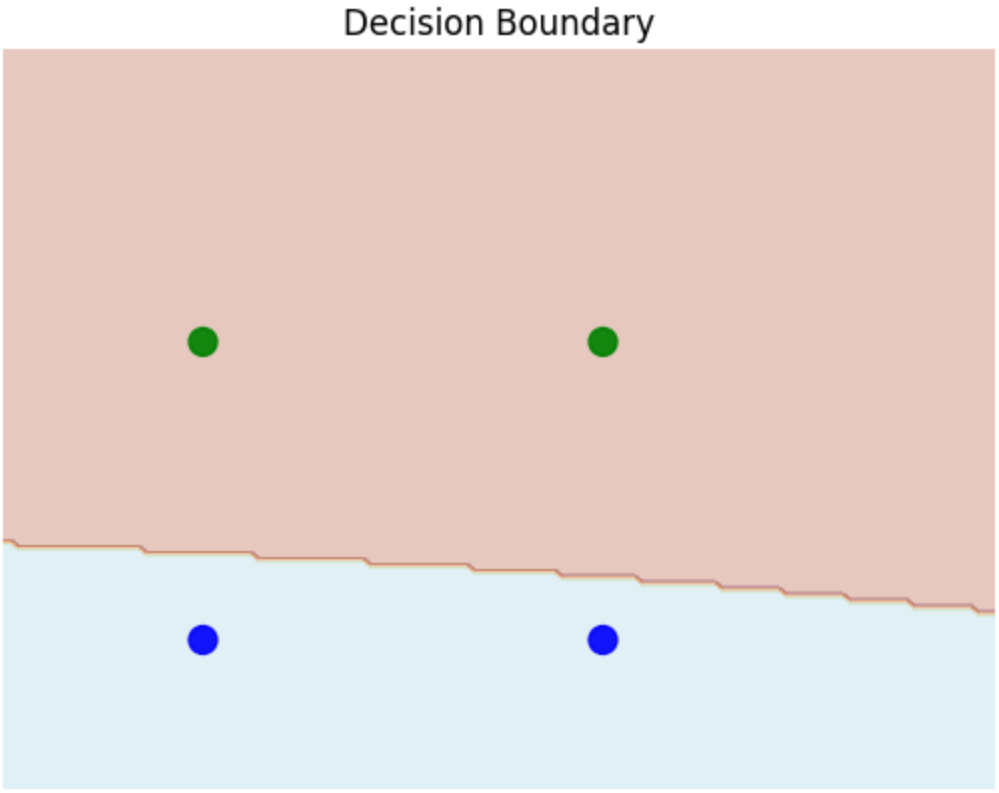
ivity_regularizer': None, 'kernel_constraint': None, 'bias_constraint': None}
[array([[0.67098737, 0.18535607],
       [0.69727856, 0.7323617 ]], dtype=float32), array([ 0.00385345, -0.1777
9478], dtype=float32)]
```




```
245/245 [==============================] - 1s 3ms/step
1/1 [==============================] - 0s 43ms/step
```




```
489/489 [==============================] - 1s 3ms/step
1/1 [==============================] - 0s 95ms/step
```



In [ ]: