Exercise 1

My final project will involve using an autoencoder-based model to predict the presence of tumours in brain scans. Tumour presence will be encoded (Yes=1,No=0), and images are taken from MRI scans from this dataset: https://www.kaggle.com/code/ruslankl/brain-tumor-detection-v1-0-cnn-vgg-16 The notebook attached to this dataset describes image preprocessing steps, which includes centering and reshaping of image scans, as well as image normalization techniques. These techniques will be used to increase the usability of the scans.

My model idea involves using an autoencoder to denoise the imaging data beforehand, and feeding the encoded features into other models to see the change in performance. An autoencoder consists of 2 parts, an encoder and a decoder. The encoder converts the input into a lower-dimensional embedding, while the decoder re-converts the embedding back into the original input. The autoencoder cost function is thus based on the similarity between the decoded output, and the original input. I have yet to decide on a specific architecture for the autoencoder, but it will likely involve 2-3 convolutional layers, and 2 dense layers.

After the autoencoder is trained, the encoder section of the model will be used to create high-level features that ideally represent our original image. I will then apply various other machine learning methods (KNN, Random Forests, Logistic Regression, DNN) with the goal of predicting on these features the presence or absence of a tumour.

The attached notebook also outlines how to use transfer learning to build imaging models. Transfer learning involves using pre-trained models for a different problem, and re-fitting them to the current problem. If I can find a pre-trained autoencoder with weights for a different problem, I will use transfer learning to retrain the model for the current problem.

Here are additional resources I have been looking into: Autoencoder tutorial by TensorFlow - https://www.tensorflow.org/tutorials/generative/autoencoder#define_a_convolutional_autoencoder Similar model idea for a different problem - https://www.frontiersin.org/articles/10.3389/fgene.2019.00233/full Original notebook - https://www.kaggle.com/code/ruslankl/brain-tumor-detection-v1-0-cnn-vgg-16

Exercise 2

In [180…
```python
import tensorflow as tf
from autograd import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
sns.set(rc = {'figure.figsize':(12,8)}) #Seaborn settings for plotting
sns.set_style("darkgrid")

from tensorflow.keras.datasets import mnist
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

In [181…
```python
train_labels.shape=(1,60000)
test_labels.shape=(1,10000)
train_images=(train_images.reshape(60000,784)).T
test_images=(test_images.reshape(10000,784)).T
print(train_images.shape)
print(test_images.shape)
print(train_labels.shape)
print(test_labels.shape)
print(train_images.dtype)
print(train_labels.dtype)
```

```
(784, 60000)
(784, 10000)
(1, 60000)
(1, 10000)
uint8
uint8
```

In [182…
```python
# compute C linear combinations of input point, one per classifier
def model(x,w):
    a = w[0] + np.dot(x.T,w[1:])
    return a.T

# multiclass perceptron
def multiclass_perceptron(w,x,y,iter):
    # get subset of points
    x_p = x[:,iter]
    y_p = y[:,iter]

    # pre-compute predictions on all points
    all_evals = model(x_p,w)

    # compute maximum across data points
    a =  np.max(all_evals,axis = 0)

    # compute cost in compact form using numpy broadcasting
    b = all_evals[y_p.astype(int).flatten(),np.arange(np.size(y_p))]
    cost = np.sum(a - b)

    # return average
    return cost/float(np.size(y_p))
```

2.1

In [183…
```python
from autograd.misc.flatten import flatten_func
from autograd import grad

# minibatch gradient descent
def minibatch_gradient_descent(g,w,x_train,y_train,alpha,max_its,batch_size):
    #Initialize weight container and cost history container
    num_samples=np.size(y_train)
    weight_history=[w]
    cost_history=[g(w,x_train,y_train,range(0,num_samples,1))] #Cost is computed for

    for k in range(max_its):
        print('Now starting Epoch: '+str(k+1)+'/'+str(max_its))
        for i in range(0,num_samples,batch_size):
            g_batch = lambda w: g(w,x_train,y_train,range(i,i+batch_size,1))
            #Set g_batch to be gradient w.r.t current batch
            if(i+batch_size>num_samples):
                #If number of samples not divisible by the batch size, then for the l
                g_batch = lambda w: g(w,x_train,y_train,range(i,num_samples-1))

            gradient = grad(g_batch)
            # evaluate the gradient
            grad_eval = gradient(w)
            # take gradient descent step for batch
            w = w - alpha*grad_eval
        # record weight and cost
        weight_history.append(w)
        cost_history.append(g(w,x_train,y_train,range(0,num_samples)))
    return weight_history,cost_history
```

2.2

In [184…
```python
C = np.size(np.unique(train_labels)) #No. of categories
N = train_images.shape[0] #No. of features
P = np.size(train_labels) #No. of samples
w = 0.1*np.random.randn(N+1,C) #Initialize weight vector
num_epochs=5
```

In [185…
```python
#Batch size of 200
weight_history_200,cost_history_200 = minibatch_gradient_descent(multiclass_perceptron
                                                                  train_labels,0.001,5,200)
```

```
Now starting Epoch: 1/5
Now starting Epoch: 2/5
Now starting Epoch: 3/5
Now starting Epoch: 4/5
Now starting Epoch: 5/5
```

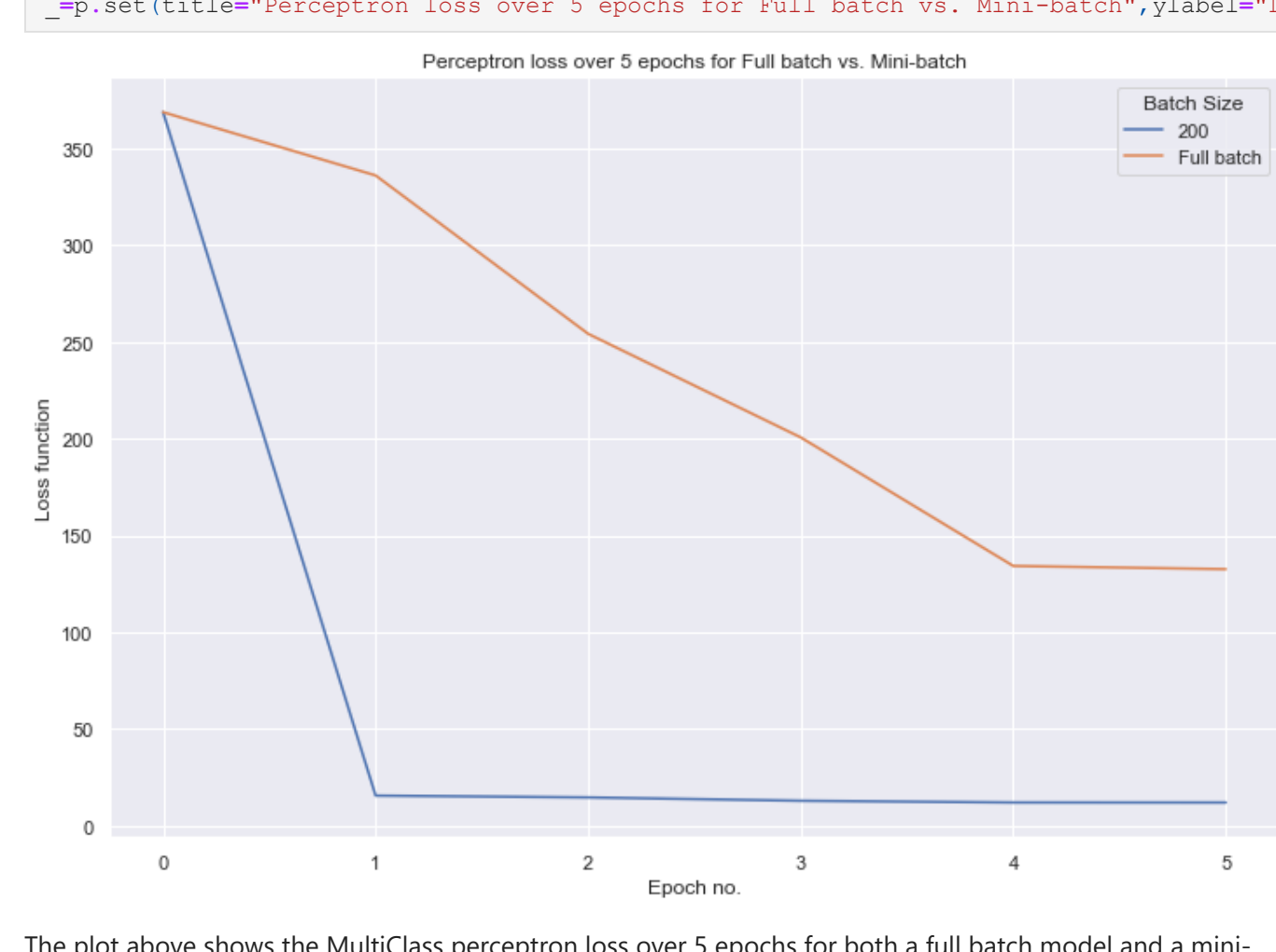
In [186…
```python
#Full batch run
weight_history_full,cost_history_full= minibatch_gradient_descent(multiclass_perceptro
                                                                  train_labels,0.001,5,P)
```

```
Now starting Epoch: 1/5
Now starting Epoch: 2/5
Now starting Epoch: 3/5
Now starting Epoch: 4/5
Now starting Epoch: 5/5
```

In [187…
```python
costs = np.hstack([cost_history_200,cost_history_full])
model_type = np.hstack([['200']*6,['Full batch']*6])
epoch_no = np.array([0,1,2,3,4,5]*2)
costs = pd.DataFrame([costs,model_type,epoch_no]).T
costs.columns=['Cost','Batch Size','Epoch no.']
```

In [188…
```python
costs['Cost']=costs['Cost'].astype(np.float64)
costs['Epoch no.']=costs['Epoch no.'].astype(np.int32)
```

In [189…
```python
p = sns.lineplot(data=costs,x='Epoch no.',y='Cost',hue='Batch Size')
_=p.set(title="Perceptron loss over 5 epochs for Full batch vs. Mini-batch",ylabel="Lo
```



The plot above shows the MultiClass perceptron loss over 5 epochs for both a full batch model and a mini-batch model with batch size set to 200. The mini-batch model converges on a better minimum in fewer epochs than the full batch model, and has a lower final cost function. Thus for this problem, a batch size of 200 is provides better model performance and is more effective for converging on local minima

2.3

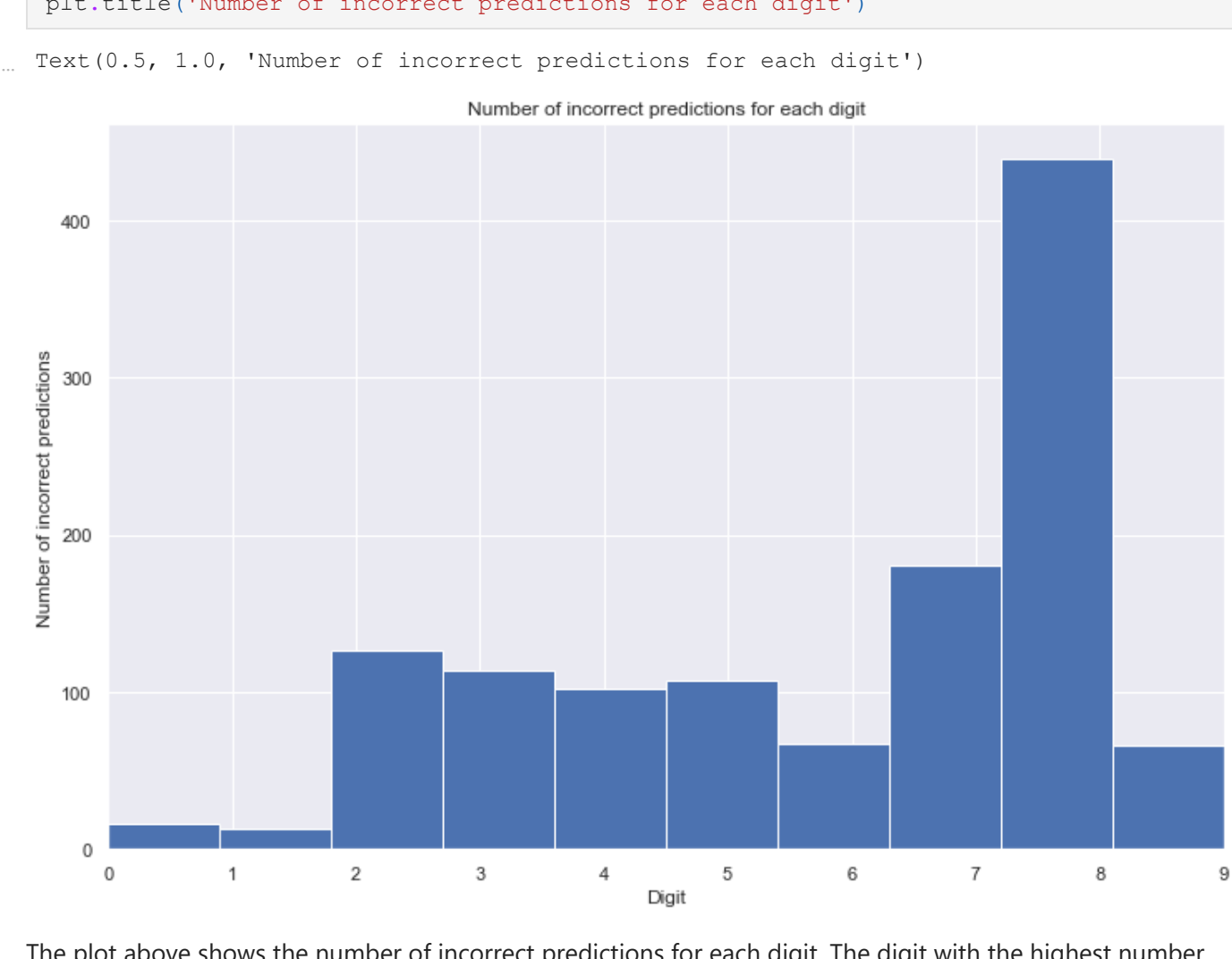
In [197…
```python
w_best=weight_history_200[np.argmin(cost_history_200)] #Get best weight
```

In [210…
```python
predictions=model(test_images,w_best) #Predictions using test images
```

In [212…
```python
class_predictions=np.argmax(predictions,axis=0) #Get predicted labels for the test se
incorrect_predictions=test_labels[np.where(test_labels!=class_predictions)] #Get inco
```

In [228…
```python
plt.hist(incorrect_predictions,bins=10,range=(0,9))
plt.xlim(0,9)
plt.ylabel('Number of incorrect predictions')
plt.xlabel('Digit')
plt.title('Number of incorrect predictions for each digit')
```

Out[228…
```
Text(0.5, 1.0, 'Number of incorrect predictions for each digit')
```



The plot above shows the number of incorrect predictions for each digit. The digit with the highest number of incorrect predictions is 8. The digit with the least number of incorrect predictinos is 0.

Exercise 3

In [244…
```python
datapath = 'Data/'
```

In [245…
```python
def model(x,C):
    w = np.matmul(C.T,x)
    return w
def autoencoder(C):
    decoded_x = np.matmul(C,model(x,C))
    cost = np.sum((decoded_x-x)**2)/x.shape[1]
    return cost
```

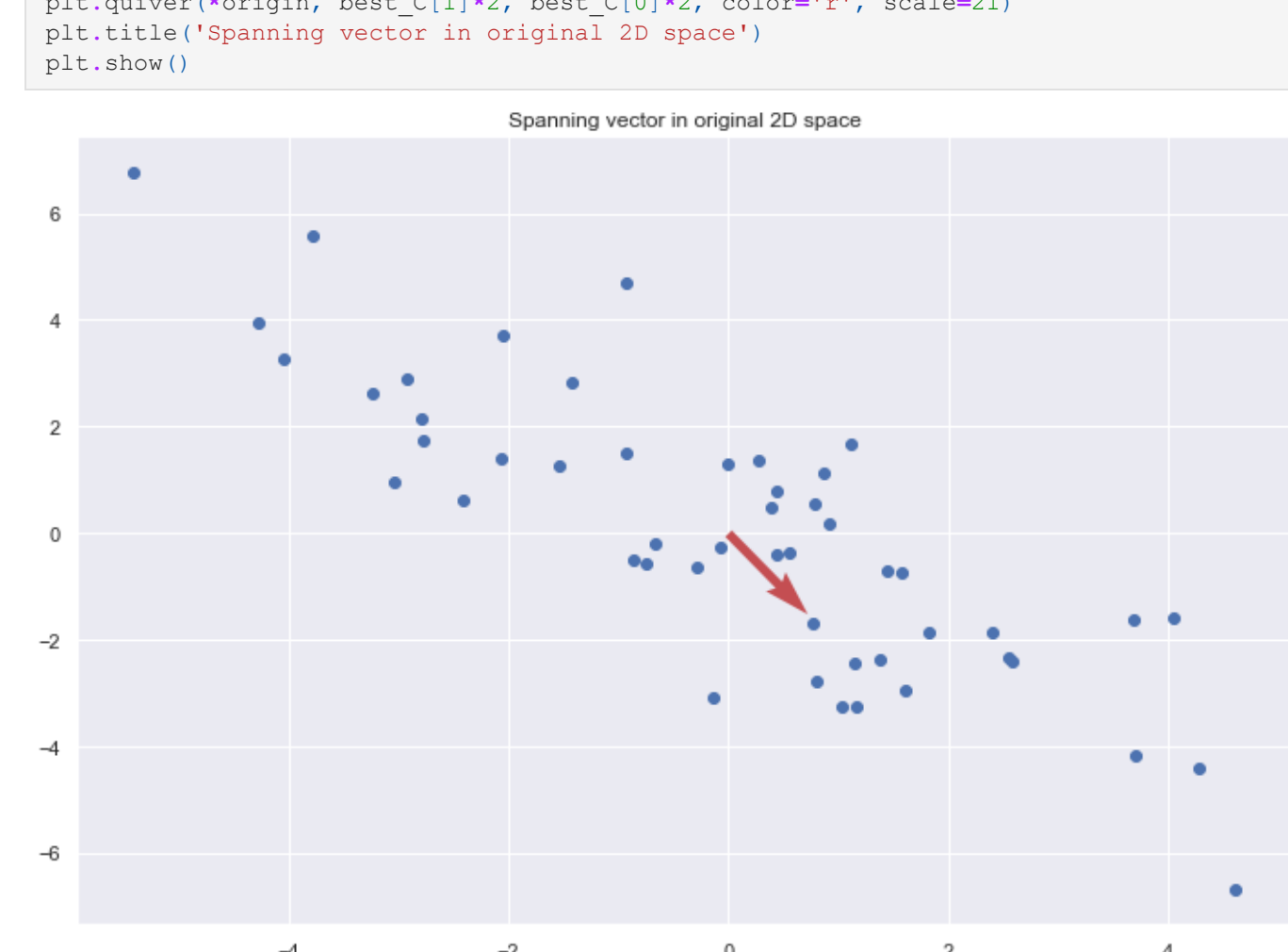
In [246…
```python
def gradient_descent(g,alpha,max_its,w):
    # compute gradient module using autograd
    gradient = grad(g)

    # run the gradient descent loop
    weight_history = [w]      # container for weight history
    cost_history = [g(w)]     # container for corresponding cost function history
    for k in range(max_its):
        # evaluate the gradient, store current weights and cost function value
        grad_eval = gradient(w)

        # take gradient descent step
        w = w - alpha*grad_eval

        # record weight and cost
        weight_history.append(w)
        cost_history.append(g(w))
    return weight_history,cost_history
```

In [247…
```python
x = np.loadtxt(datapath + '2d_span_data_centered.csv',delimiter=',')
C = np.array([[-3.5],[3.5]])
g = autoencoder; alpha_choice = 10**(-4); max_its = 1000; C = 0.1*np.random.randn(2,1
```

In [248…
```python
C_history,cost_history=gradient_descent(g,alpha_choice,max_its,C)
```

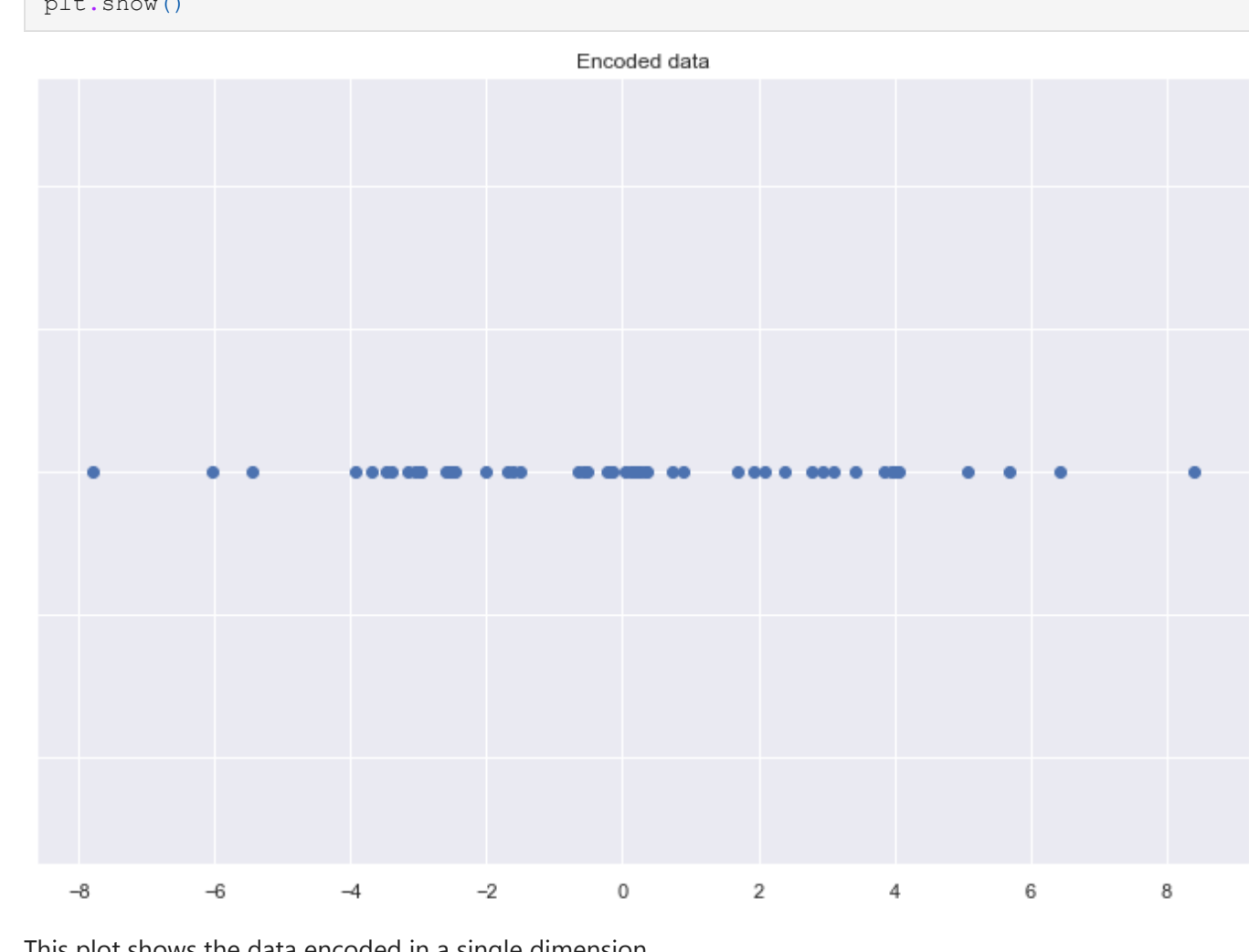
In [249…
```python
best_C = C_history[np.argmin(cost_history)]
encoded_x = model(x,best_C)
decoded_x = np.matmul(C,encoded_x)
```

In [254…
```python
plt.scatter(x[0],x[1])
origin = np.array([[0],[0]]) # origin point
plt.quiver(*origin, best_C[1]*2, best_C[0]*2, color='r', scale=21)
plt.title('Spanning vector in original 2D space')
plt.show()
```



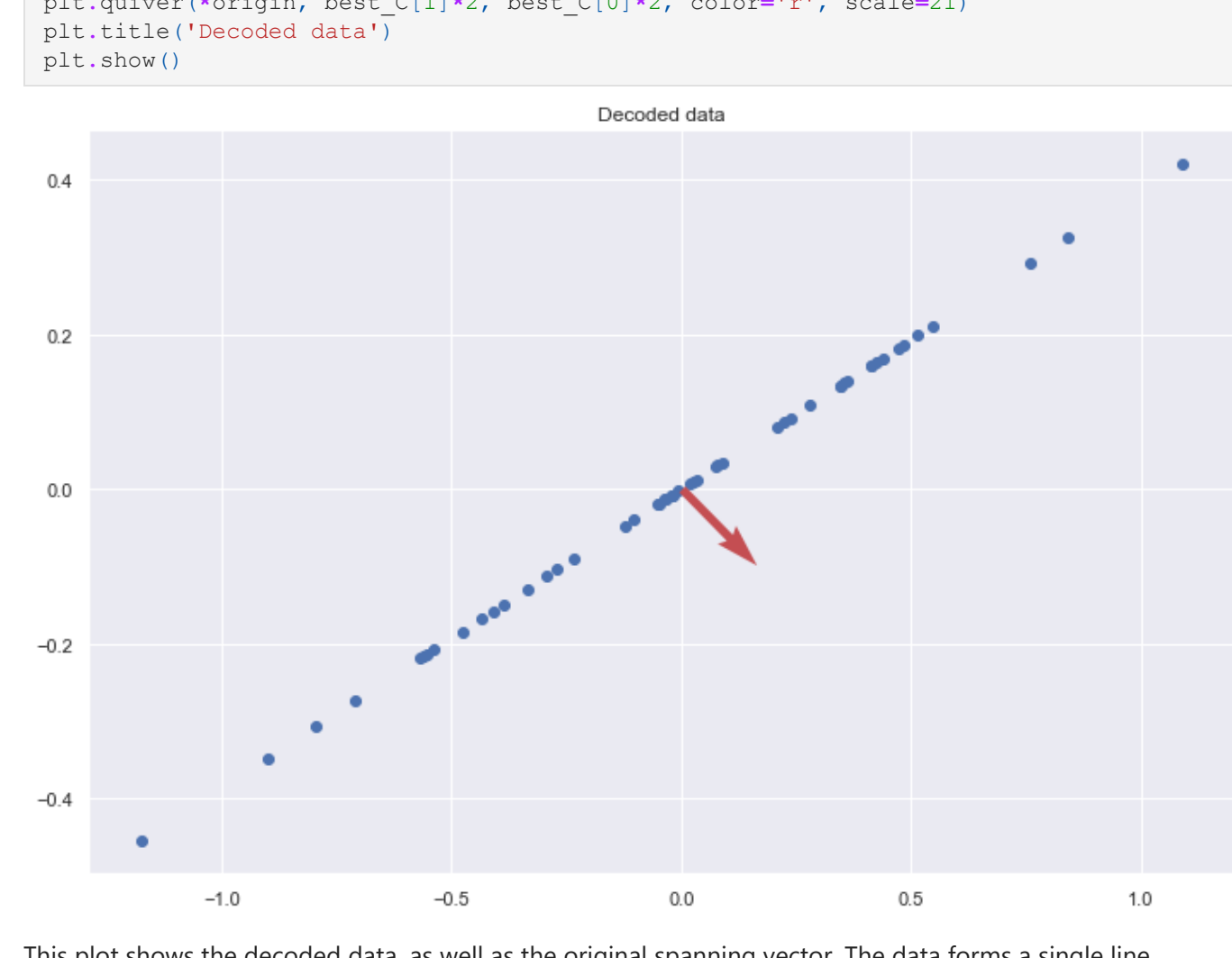
This plot shows the data, as well as the spanning vector in the original 2D space. The spanning vector shows a good fit with the data.

In [255…
```python
val = 0.
plt.plot(encoded_x, np.zeros_like(encoded_x) + val,'o',c='b')
plt.tick_params(left=False,labelleft=False)
plt.title('Encoded data')
plt.show()
```



This plot shows the data encoded in a single dimension.

In [264…
```python
plt.scatter(decoded_x[0],decoded_x[1])
origin = np.array([[0],[0]]) # origin point
plt.quiver(*origin, best_C[1]*2, best_C[0]*2, color='r', scale=21)
plt.title('Decoded data')
plt.show()
```



This plot shows the decoded data, as well as the original spanning vector. The data forms a single line orthogonal ot the spanning vector, and some of the original encoded data has been lost.

Exercise 4

In [273…
```python
def center(X):
    X_means = np.mean(X,axis=1)[:,np.newaxis]
    X_normalized = X - X_means

    return X_normalized

def compute_pcs(X,lam):
    # create the correlation matrix
    P = float(X.shape[1])
    Cov = 1/P*np.dot(X,X.T) + lam*np.eye(X.shape[0])

    # use numpy function to compute eigenvalues / vectors of correlation matrix
    D,V = np.linalg.eigh(Cov)
    return D,V
```

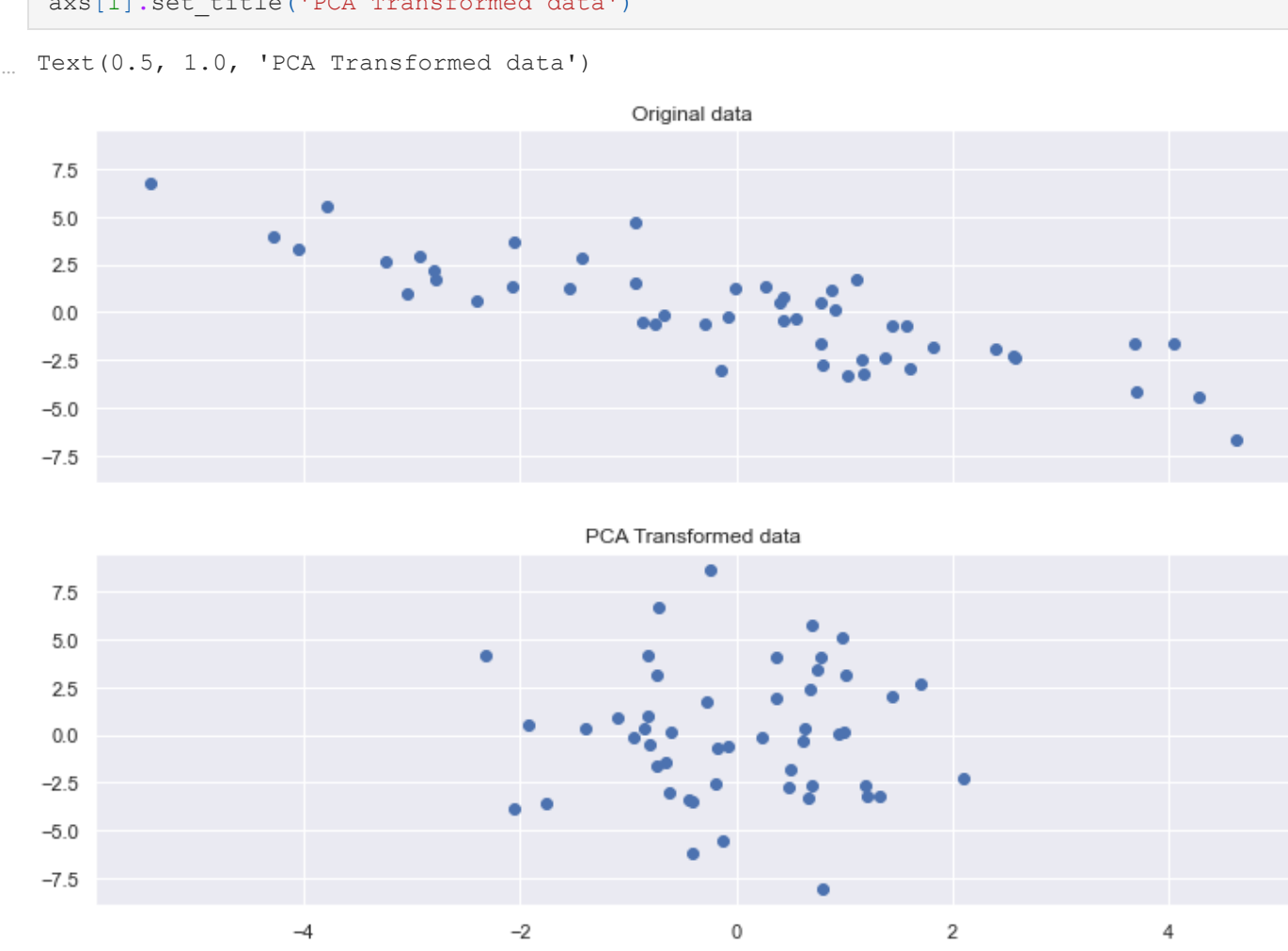
In [274…
```python
X_original = np.loadtxt(datapath + '2d_span_data.csv',delimiter=',') #Load data
X_centered = center(X_original) #Center data
D,V=compute_pcs(X_centered,10e-5) #Get principal components
```

In [275…
```python
X_centered.shape
```

Out[275…
```
(2, 50)
```

In [279…
```python
fig,axs=plt.subplots(2,sharex=True,sharey=True)
axs[0].scatter(X_centered[0],X_centered[1])
axs[0].set_title('Original data')
projected = np.dot(V.T,X_centered)
axs[1].scatter(projected[0],projected[1])
axs[1].set_title('PCA Transformed data')
```

Out[279…
```
Text(0.5, 1.0, 'PCA Transformed data')
```



The plots above show the 2d span data in its original space, and in the PCA transformed space. The PCA transformed space has a smaller minimum and maximum, suggesting suitable transformation has taken place.

Exercise 5

In [280…
```python
def update_assignments(data,centroids):
    assignments = []
    for i in data.T:
        assignment = np.argmin(np.sum((centroids - i)**2,axis=1))
        assignments.append(assignment)
    return np.array(assignments)

def update_centroids(data,old_centroids,assignments):
    new_centroids = []
    for i in range(len(old_centroids)):
        points = data[:,np.where(assignments==i)]
        new_centroid = np.mean(data[:,np.where(assignments==i)[0]],axis=1)
        new_centroids.append(new_centroid)
    return np.array(new_centroids)
```

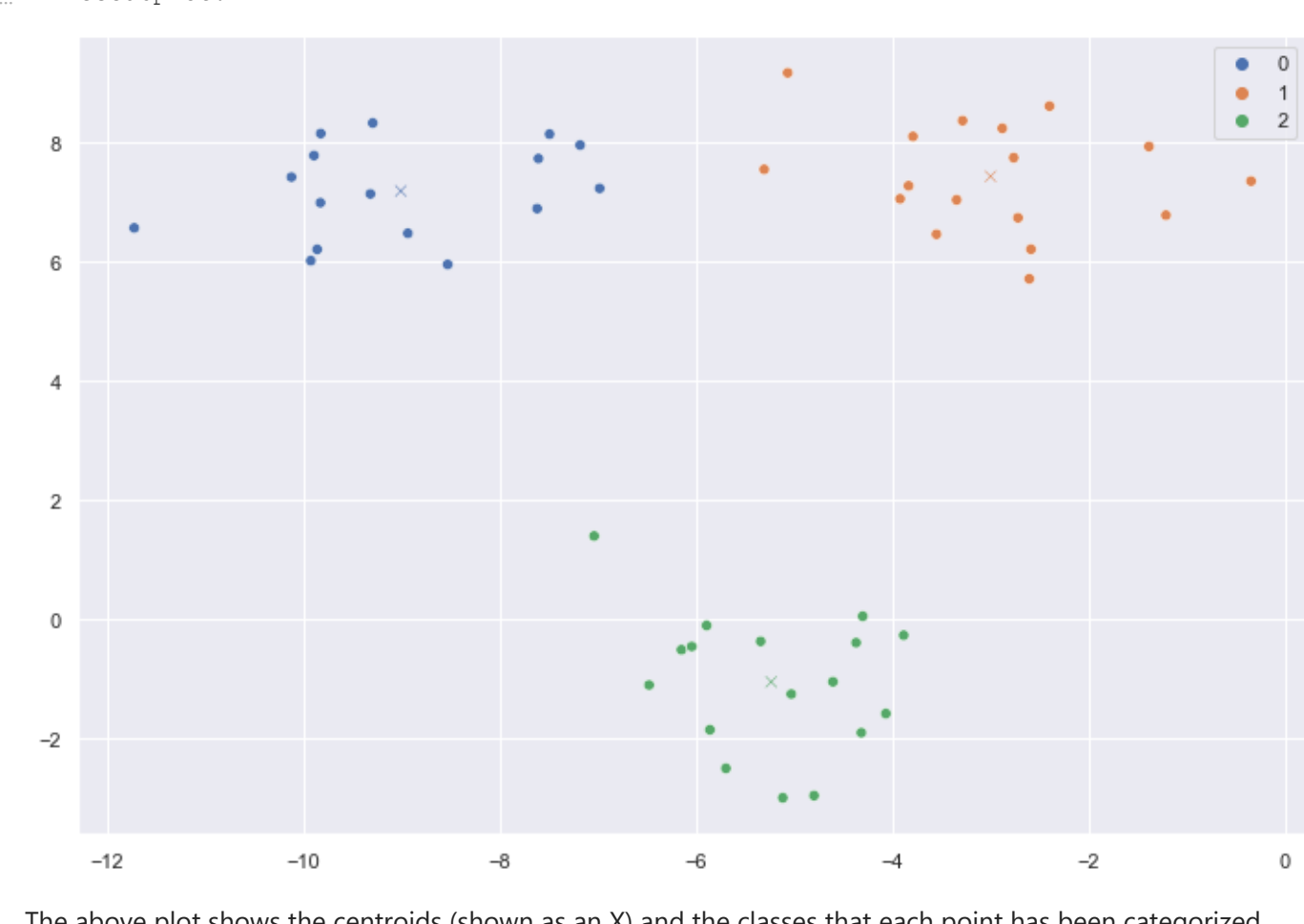
In [281…
```python
data = np.loadtxt(datapath+'blobs.dat')
```

In [282…
```python
#Run K-means for 3 centroids and over 5 iterations
K = 3
no_its = 5
centroids = np.array([[-8,4],[0,4],[-3,-1]])
assignments = update_assignments(data,centroids)
centroid_history = [centroids]
for i in range(no_its):
    centroids = update_centroids(data,centroids,assignments)
    assignments = update_assignments(data,centroids)
    centroid_history.append(centroids)
```

In [284…
```python
sns.scatterplot(data[0],data[1],hue=assignments.astype(str))
sns.scatterplot(centroids[:,0],centroids[:,1],hue=np.array(['0','1','2']),marker='x',
```

```
C:\Users\nicho\anaconda3\lib\site-packages\seaborn\_decorators.py:36: FutureWarning: P
ass the following variables as keyword args: x, y. From version 0.12, the only valid p
ositional argument will be `data`, and passing other arguments without an explicit key
word will result in an error or misinterpretation.
  warnings.warn(
C:\Users\nicho\anaconda3\lib\site-packages\seaborn\_decorators.py:36: FutureWarning: P
ass the following variables as keyword args: x, y. From version 0.12, the only valid p
ositional argument will be `data`, and passing other arguments without an explicit key
word will result in an error or misinterpretation.
  warnings.warn(
```

Out[284…
```
<AxesSubplot:>
```

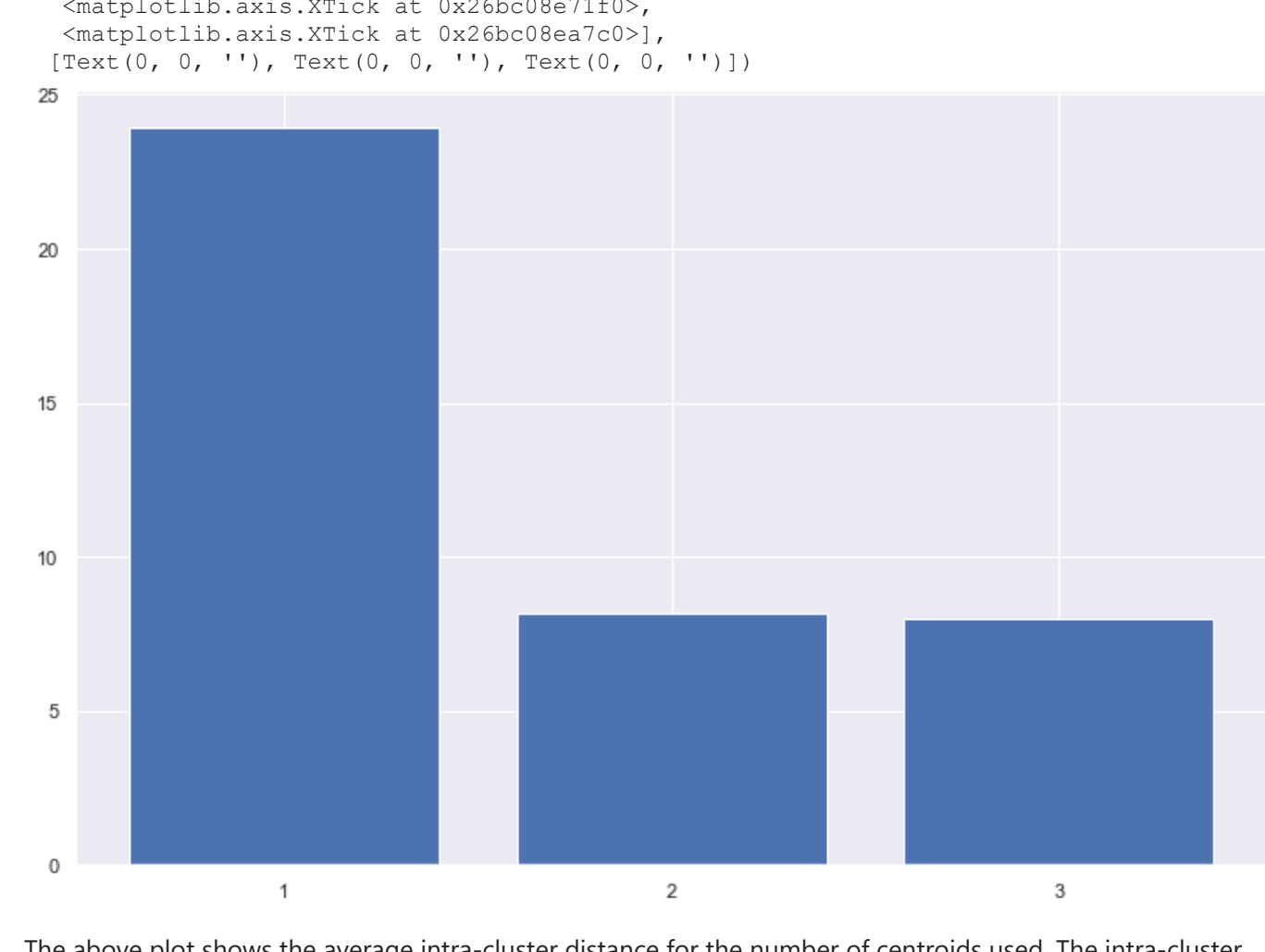


The above plot shows the centroids (shown as an X) and the classes that each point has been categorized into by the K-Means clustering. Visually, the plot shows that the clustering has been successful, as the centroids fall in the center of each 'blob' and each blob's points has been categorized in the appropriate class.

In [368…
```python
distances = []
for K in range(1,11):
    np.random.seed(2)
    centroids = np.random.randn(K,2)*3
    assignments = update_assignments(data,centroids)
    for i in range(no_its):
        centroids = update_centroids(data,centroids,assignments)
        assignments = update_assignments(data,centroids)
    total_distance=0.0
    for i in range(len(centroids)):
        points = data[:,np.where(assignments==i)[0]]
        centroid=centroids[i]
        distance = np.sum((points.T-centroid)**2)
        total_distance+=distance
    distances.append(total_distance/len(assignments))
```

In [376…
```python
plt.bar(x=[1,2,3,4,5,6,7,8,9,10],height=distances)
plt.xticks([1,2,3])
```

Out[376…
```
([<matplotlib.axis.XTick at 0x26bc08e7220>,
  <matplotlib.axis.XTick at 0x26bc08e71f0>,
  <matplotlib.axis.XTick at 0x26bc08ea7c0>],
 [Text(0, 0, ''), Text(0, 0, ''), Text(0, 0, '')])
```



The above plot shows the average intra-cluster distance for the number of centroids used. The intra-cluster distance for K-Means with more than 3 centroids returned NA, suggesting that the model could not properly converge on an appropriate clustering. According to the above plot, using 3 centroids is ideal for K-Means

Exercise 6

In [377…
```python
import numpy as np
from urllib.request import urlopen
url = 'http://archive.ics.uci.edu/ml/machine-learning-databases/00267/data_banknote_a
raw_data = urlopen(url)
dataset = np.loadtxt(raw_data, delimiter=",")
print(dataset.shape)
```

```
(1372, 5)
```

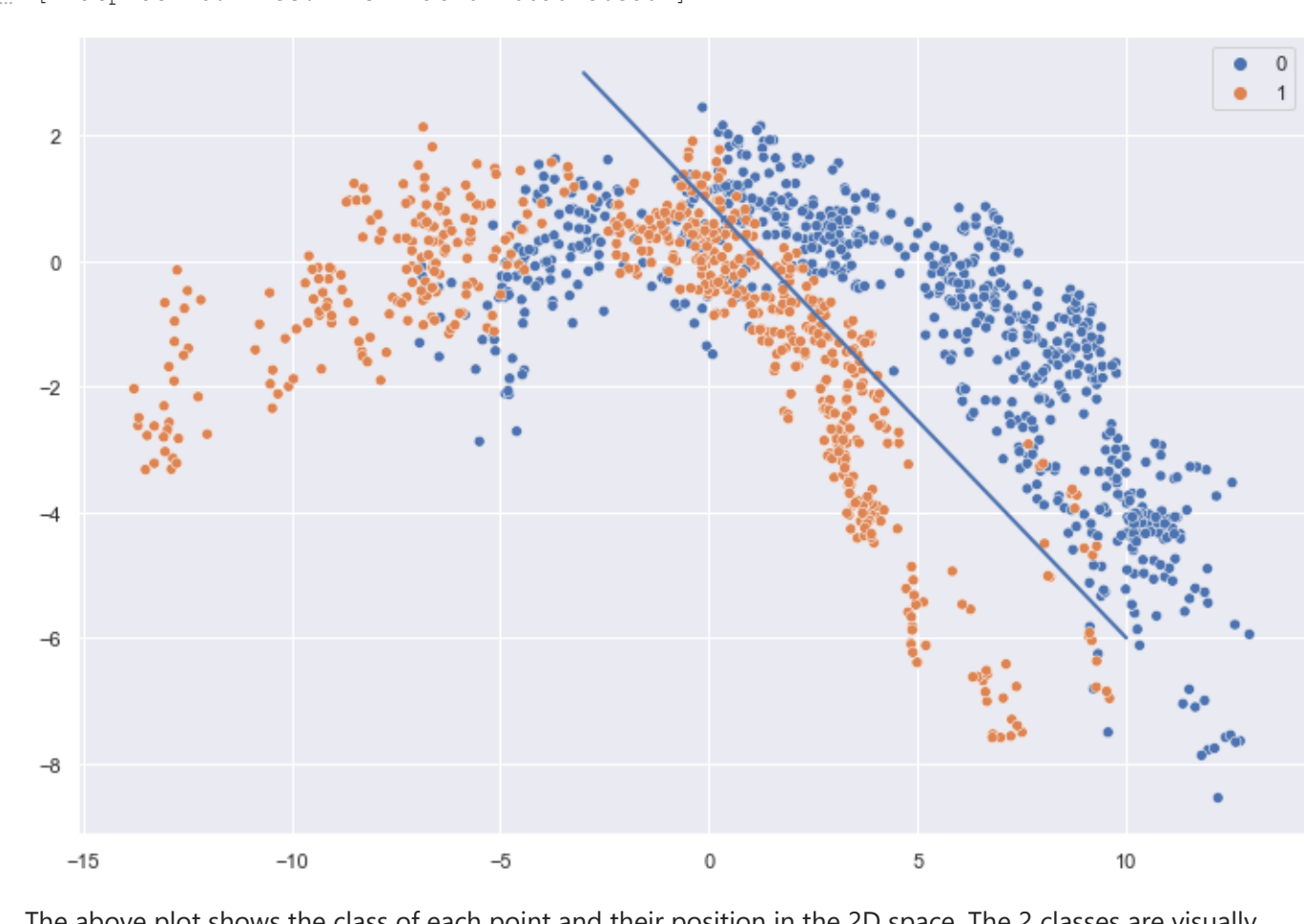
In [378…
```python
X=dataset[:,[1,3]]
Y=dataset[:,4]
print(X.shape)
print(Y.shape)
```

```
(1372, 2)
(1372,)
```

In [386…
```python
sns.scatterplot(X[:,0],X[:,1],hue=Y.astype(int).astype(str))
plt.plot([10, -3], [-6, 3], linewidth=2)
```

```
C:\Users\nicho\anaconda3\lib\site-packages\seaborn\_decorators.py:36: FutureWarning: P
ass the following variables as keyword args: x, y. From version 0.12, the only valid p
ositional argument will be `data`, and passing other arguments without an explicit key
word will result in an error or misinterpretation.
  warnings.warn(
```

Out[386…
```
[<matplotlib.lines.Line2D at 0x26bad1e6e50>]
```



The above plot shows the class of each point and their position in the 2D space. The 2 classes are visually not linearly separable. An example line of separation has been plotted, however there remain a large number of points of class 0 that overlap with points of class 1 to the left of the line.

In [387…
```python
from tensorflow.keras.layers import Dense
import tensorflow as tf
from tensorflow import keras

opt = tf.keras.optimizers.SGD(learning_rate=0.15)
model = keras.Sequential()
model.add(Dense(1, batch_input_shape=(None, 2),activation='sigmoid'))
model.compile(opt,loss='binary_crossentropy',metrics=['accuracy'])
history=model.fit(X,Y,batch_size=128,epochs=400)
```

```
Epoch 1/400
11/11 [==============================] - 5s 5ms/step - loss: 0.8082 - accuracy: 0.5195
Epoch 2/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5318 - accuracy: 0.6919
Epoch 3/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5132 - accuracy: 0.7141
Epoch 4/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5224 - accuracy: 0.7268
Epoch 5/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5090 - accuracy: 0.7359
Epoch 6/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5234 - accuracy: 0.7164
Epoch 7/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5236 - accuracy: 0.7143
Epoch 8/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4973 - accuracy: 0.7338
Epoch 9/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5254 - accuracy: 0.7078
Epoch 10/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5056 - accuracy: 0.7113
Epoch 11/400
11/11 [==============================] - 0s 998us/step - loss: 0.5191 - accuracy: 0.70
68
Epoch 12/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5224 - accuracy: 0.6877
Epoch 13/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5213 - accuracy: 0.7078
Epoch 14/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5201 - accuracy: 0.7050
Epoch 15/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5064 - accuracy: 0.7052
Epoch 16/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5089 - accuracy: 0.7137
Epoch 17/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4977 - accuracy: 0.7171
Epoch 18/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5065 - accuracy: 0.7127
Epoch 19/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5045 - accuracy: 0.7087
Epoch 20/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5103 - accuracy: 0.7128
Epoch 21/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4919 - accuracy: 0.7240
Epoch 22/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5081 - accuracy: 0.7250
Epoch 23/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5121 - accuracy: 0.7070
Epoch 24/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5000 - accuracy: 0.7210
Epoch 25/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5304 - accuracy: 0.7049
Epoch 26/400
11/11 [==============================] - 0s 971us/step - loss: 0.5044 - accuracy: 0.72
35
Epoch 27/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5334 - accuracy: 0.7061
Epoch 28/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5070 - accuracy: 0.7086
Epoch 29/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5187 - accuracy: 0.7069
Epoch 30/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5110 - accuracy: 0.6951
Epoch 31/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5006 - accuracy: 0.7258
Epoch 32/400
11/11 [==============================] - 0s 872us/step - loss: 0.5191 - accuracy: 0.70
03
Epoch 33/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5155 - accuracy: 0.7125
Epoch 34/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5171 - accuracy: 0.6963
Epoch 35/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4963 - accuracy: 0.7162
Epoch 36/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5049 - accuracy: 0.7119
Epoch 37/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5032 - accuracy: 0.7120
Epoch 38/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5119 - accuracy: 0.7090
Epoch 39/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4969 - accuracy: 0.7204
Epoch 40/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5200 - accuracy: 0.7124
Epoch 41/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5211 - accuracy: 0.7077
Epoch 42/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5044 - accuracy: 0.7074
Epoch 43/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5046 - accuracy: 0.7179
Epoch 44/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5194 - accuracy: 0.7028
Epoch 45/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5114 - accuracy: 0.7066
Epoch 46/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5037 - accuracy: 0.7111
Epoch 47/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5232 - accuracy: 0.6996
Epoch 48/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4918 - accuracy: 0.7117
Epoch 49/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5310 - accuracy: 0.6944
Epoch 50/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5081 - accuracy: 0.7140
Epoch 51/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5126 - accuracy: 0.7040
Epoch 52/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5099 - accuracy: 0.7010
Epoch 53/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4972 - accuracy: 0.7195
Epoch 54/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5016 - accuracy: 0.7117
Epoch 55/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4914 - accuracy: 0.7259
Epoch 56/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5126 - accuracy: 0.7184
Epoch 57/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5175 - accuracy: 0.7028
Epoch 58/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5167 - accuracy: 0.7020
Epoch 59/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4996 - accuracy: 0.7177
Epoch 60/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5072 - accuracy: 0.7217
Epoch 61/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5182 - accuracy: 0.7013
Epoch 62/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5189 - accuracy: 0.7106
Epoch 63/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5271 - accuracy: 0.7041
Epoch 64/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5211 - accuracy: 0.6975
Epoch 65/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5169 - accuracy: 0.6969
Epoch 66/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5146 - accuracy: 0.7039
Epoch 67/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5211 - accuracy: 0.7008
Epoch 68/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5125 - accuracy: 0.7022
Epoch 69/400
11/11 [==============================] - 0s 998us/step - loss: 0.5111 - accuracy: 0.71
41
Epoch 70/400
11/11 [==============================] - 0s 943us/step - loss: 0.5375 - accuracy: 0.68
99
Epoch 71/400
11/11 [==============================] - 0s 997us/step - loss: 0.5212 - accuracy: 0.70
67
Epoch 72/400
11/11 [==============================] - 0s 900us/step - loss: 0.5059 - accuracy: 0.70
59
Epoch 73/400
11/11 [==============================] - ETA: 0s - loss: 0.5837 - accuracy: 0.61 - 0s
997us/step - loss: 0.5243 - accuracy: 0.6873
Epoch 74/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5290 - accuracy: 0.7005
Epoch 75/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5214 - accuracy: 0.7045
Epoch 76/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5200 - accuracy: 0.6964
Epoch 77/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5187 - accuracy: 0.7021
Epoch 78/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4960 - accuracy: 0.7228
Epoch 79/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5063 - accuracy: 0.7187
Epoch 80/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5031 - accuracy: 0.7145
Epoch 81/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5149 - accuracy: 0.7046
Epoch 82/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5161 - accuracy: 0.7185
Epoch 83/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5122 - accuracy: 0.7123
Epoch 84/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4970 - accuracy: 0.7258
Epoch 85/400
11/11 [==============================] - 0s 1000us/step - loss: 0.5090 - accuracy: 0.7
072
Epoch 86/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5278 - accuracy: 0.7101
Epoch 87/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4860 - accuracy: 0.7310
Epoch 88/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5185 - accuracy: 0.7047
Epoch 89/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5166 - accuracy: 0.7104
Epoch 90/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5023 - accuracy: 0.7281
Epoch 91/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5033 - accuracy: 0.7211
Epoch 92/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5267 - accuracy: 0.6927
Epoch 93/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5336 - accuracy: 0.6898
Epoch 94/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5207 - accuracy: 0.7093
Epoch 95/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5108 - accuracy: 0.7101
Epoch 96/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4978 - accuracy: 0.7227
Epoch 97/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5054 - accuracy: 0.7248
```

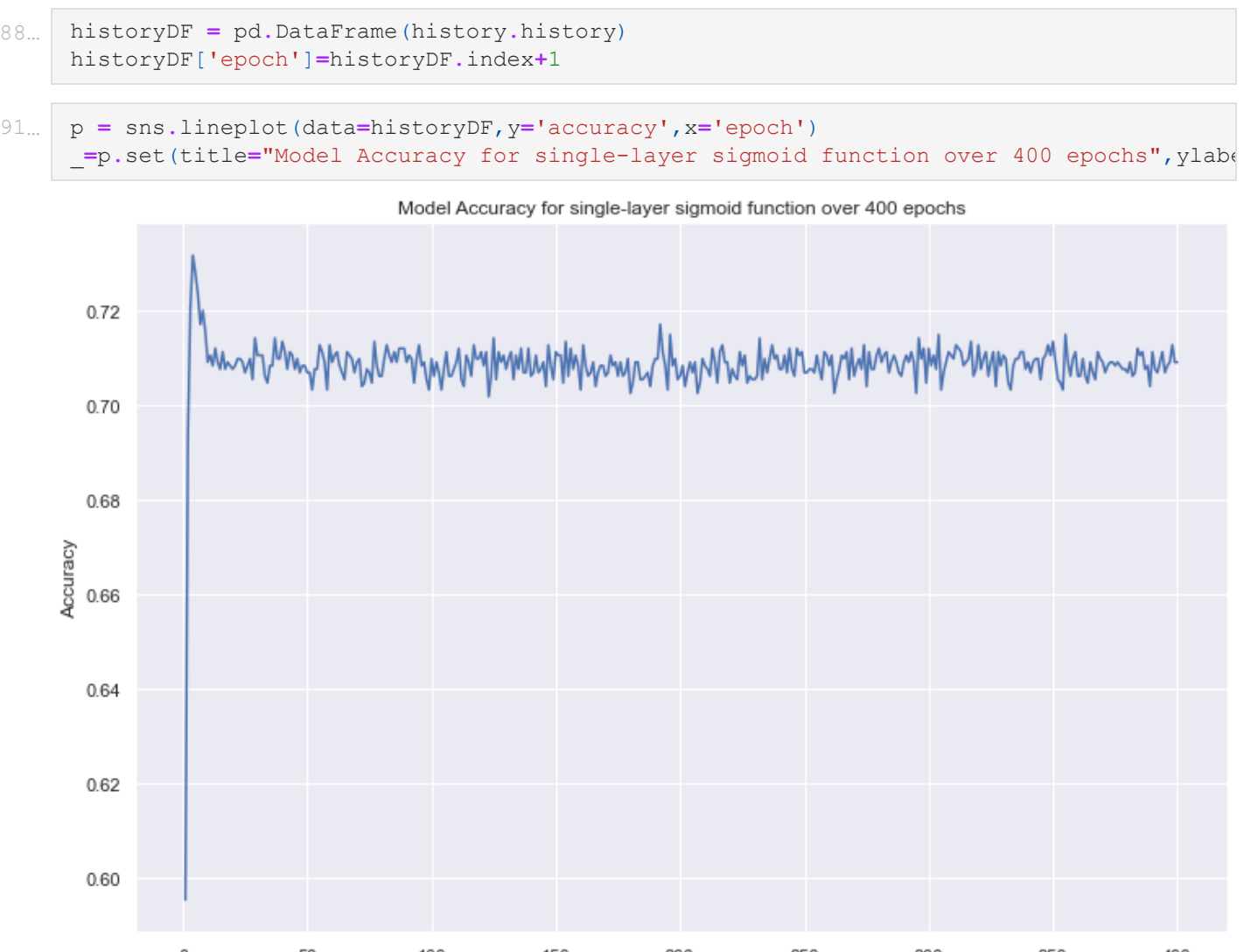
```
Epoch 98/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5123 - accuracy: 0.7012
Epoch 99/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5072 - accuracy: 0.7112
Epoch 100/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5144 - accuracy: 0.7148
Epoch 101/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5013 - accuracy: 0.7106
Epoch 102/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5118 - accuracy: 0.7210
Epoch 103/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5127 - accuracy: 0.7044
Epoch 104/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5032 - accuracy: 0.7207
Epoch 105/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5212 - accuracy: 0.7065
Epoch 106/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5085 - accuracy: 0.7125
Epoch 107/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5057 - accuracy: 0.7161
Epoch 108/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5177 - accuracy: 0.7004
Epoch 109/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5101 - accuracy: 0.7101
Epoch 110/400
11/11 [==============================] - 0s 997us/step - loss: 0.5132 - accuracy: 0.70
13
Epoch 111/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5255 - accuracy: 0.6982
Epoch 112/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5039 - accuracy: 0.7171
Epoch 113/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5178 - accuracy: 0.7006
Epoch 114/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5191 - accuracy: 0.7129
Epoch 115/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5112 - accuracy: 0.7118
Epoch 116/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5123 - accuracy: 0.7159
Epoch 117/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5098 - accuracy: 0.7175
Epoch 118/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5140 - accuracy: 0.7143
Epoch 119/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5248 - accuracy: 0.6984
Epoch 120/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5251 - accuracy: 0.6946
Epoch 121/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5175 - accuracy: 0.7167
Epoch 122/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4998 - accuracy: 0.7146
Epoch 123/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5064 - accuracy: 0.7038
Epoch 124/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5163 - accuracy: 0.7060
Epoch 125/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5108 - accuracy: 0.7067
Epoch 126/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5144 - accuracy: 0.7010
Epoch 127/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5160 - accuracy: 0.7092
Epoch 128/400
11/11 [==============================] - 0s 995us/step - loss: 0.5256 - accuracy: 0.69
49
Epoch 129/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5138 - accuracy: 0.7073
Epoch 130/400
11/11 [==============================] - 0s 997us/step - loss: 0.5372 - accuracy: 0.69
13
Epoch 131/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5184 - accuracy: 0.7024
Epoch 132/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5023 - accuracy: 0.7142
Epoch 133/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5190 - accuracy: 0.7011
Epoch 134/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5147 - accuracy: 0.7030
Epoch 135/400
11/11 [==============================] - 0s 959us/step - loss: 0.5252 - accuracy: 0.70
66
Epoch 136/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4836 - accuracy: 0.7310
Epoch 137/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5059 - accuracy: 0.7242
Epoch 138/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5241 - accuracy: 0.7032
Epoch 139/400
11/11 [==============================] - 0s 969us/step - loss: 0.5057 - accuracy: 0.70
38
Epoch 140/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5126 - accuracy: 0.7149
Epoch 141/400
11/11 [==============================] - 0s 997us/step - loss: 0.5048 - accuracy: 0.71
68
Epoch 142/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5043 - accuracy: 0.7138
Epoch 143/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5387 - accuracy: 0.6905
Epoch 144/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5163 - accuracy: 0.7088
Epoch 145/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5097 - accuracy: 0.7176
Epoch 146/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4917 - accuracy: 0.7328
Epoch 147/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5168 - accuracy: 0.7177
Epoch 148/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5052 - accuracy: 0.7156
Epoch 149/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5214 - accuracy: 0.7123
Epoch 150/400
11/11 [==============================] - 0s 993us/step - loss: 0.5109 - accuracy: 0.71
37
Epoch 151/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4841 - accuracy: 0.7318
Epoch 152/400
11/11 [==============================] - 0s 997us/step - loss: 0.5206 - accuracy: 0.70
07
Epoch 153/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5296 - accuracy: 0.6917
Epoch 154/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4969 - accuracy: 0.7215
Epoch 155/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5147 - accuracy: 0.7059
Epoch 156/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5107 - accuracy: 0.7119
Epoch 157/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5216 - accuracy: 0.6884
Epoch 158/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5140 - accuracy: 0.7067
Epoch 159/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5047 - accuracy: 0.7105
Epoch 160/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5088 - accuracy: 0.7144
Epoch 161/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5270 - accuracy: 0.6931
Epoch 162/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4824 - accuracy: 0.7314
Epoch 163/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5139 - accuracy: 0.7021
Epoch 164/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5147 - accuracy: 0.7155
Epoch 165/400
11/11 [==============================] - 0s 967us/step - loss: 0.5110 - accuracy: 0.70
47
Epoch 166/400
11/11 [==============================] - 0s 901us/step - loss: 0.5063 - accuracy: 0.70
91
Epoch 167/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4847 - accuracy: 0.7349
Epoch 168/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5315 - accuracy: 0.6909
Epoch 169/400
11/11 [==============================] - 0s 997us/step - loss: 0.5151 - accuracy: 0.70
28
Epoch 170/400
11/11 [==============================] - 0s 993us/step - loss: 0.5211 - accuracy: 0.70
55
Epoch 171/400
11/11 [==============================] - 0s 993us/step - loss: 0.5192 - accuracy: 0.70
70
Epoch 172/400
11/11 [==============================] - 0s 985us/step - loss: 0.5120 - accuracy: 0.71
44
Epoch 173/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5236 - accuracy: 0.6874
Epoch 174/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5177 - accuracy: 0.7129
Epoch 175/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5043 - accuracy: 0.7131
Epoch 176/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5213 - accuracy: 0.6971
Epoch 177/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5002 - accuracy: 0.7155
Epoch 178/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5204 - accuracy: 0.7066
Epoch 179/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5261 - accuracy: 0.7039
Epoch 180/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4968 - accuracy: 0.7121
Epoch 181/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4999 - accuracy: 0.7148
Epoch 182/400
11/11 [==============================] - 0s 997us/step - loss: 0.5007 - accuracy: 0.72
29
Epoch 183/400
11/11 [==============================] - 0s 824us/step - loss: 0.5160 - accuracy: 0.70
63
Epoch 184/400
11/11 [==============================] - 0s 898us/step - loss: 0.5136 - accuracy: 0.70
73
Epoch 185/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5251 - accuracy: 0.6868
Epoch 186/400
11/11 [==============================] - 0s 997us/step - loss: 0.5063 - accuracy: 0.72
25
Epoch 187/400
11/11 [==============================] - 0s 999us/step - loss: 0.5193 - accuracy: 0.70
12
Epoch 188/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5187 - accuracy: 0.6968
Epoch 189/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5017 - accuracy: 0.7231
Epoch 190/400
11/11 [==============================] - 0s 901us/step - loss: 0.5153 - accuracy: 0.70
93
Epoch 191/400
11/11 [==============================] - 0s 997us/step - loss: 0.5138 - accuracy: 0.70
77
Epoch 192/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5145 - accuracy: 0.7311
Epoch 193/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5040 - accuracy: 0.7275
Epoch 194/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5124 - accuracy: 0.7141
Epoch 195/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5269 - accuracy: 0.6909
Epoch 196/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5040 - accuracy: 0.7071
Epoch 197/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5214 - accuracy: 0.7018
Epoch 198/400
11/11 [==============================] - 0s 998us/step - loss: 0.5180 - accuracy: 0.70
64
Epoch 199/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5312 - accuracy: 0.6863
Epoch 200/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5034 - accuracy: 0.7119
Epoch 201/400
11/11 [==============================] - 0s 997us/step - loss: 0.5040 - accuracy: 0.71
89
Epoch 202/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5013 - accuracy: 0.7092
Epoch 203/400
11/11 [==============================] - 0s 997us/step - loss: 0.5133 - accuracy: 0.70
15
Epoch 204/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5252 - accuracy: 0.6971
Epoch 205/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5088 - accuracy: 0.7067
Epoch 206/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5043 - accuracy: 0.7127
Epoch 207/400
11/11 [==============================] - 0s 997us/step - loss: 0.4951 - accuracy: 0.72
10
Epoch 208/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5081 - accuracy: 0.7173
Epoch 209/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5336 - accuracy: 0.6866
Epoch 210/400
11/11 [==============================] - 0s 999us/step - loss: 0.5202 - accuracy: 0.70
88
Epoch 211/400
11/11 [==============================] - 0s 892us/step - loss: 0.5152 - accuracy: 0.70
69
Epoch 212/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5277 - accuracy: 0.6928
Epoch 213/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5032 - accuracy: 0.7234
Epoch 214/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5047 - accuracy: 0.7254
Epoch 215/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5278 - accuracy: 0.6962
Epoch 216/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5119 - accuracy: 0.7139
Epoch 217/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5060 - accuracy: 0.7188
Epoch 218/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5032 - accuracy: 0.7110
Epoch 219/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5024 - accuracy: 0.7140
Epoch 220/400
11/11 [==============================] - 0s 997us/step - loss: 0.5142 - accuracy: 0.70
46
Epoch 221/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5021 - accuracy: 0.7226
Epoch 222/400
11/11 [==============================] - 0s 898us/step - loss: 0.4935 - accuracy: 0.72
46
Epoch 223/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5299 - accuracy: 0.6849
Epoch 224/400
11/11 [==============================] - 0s 998us/step - loss: 0.5067 - accuracy: 0.72
29
Epoch 225/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5133 - accuracy: 0.7166
Epoch 226/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5061 - accuracy: 0.7199
Epoch 227/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5249 - accuracy: 0.6926
Epoch 228/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5127 - accuracy: 0.7110
Epoch 229/400
11/11 [==============================] - 0s 997us/step - loss: 0.5211 - accuracy: 0.69
27
Epoch 230/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5227 - accuracy: 0.6974
Epoch 231/400
11/11 [==============================] - 0s 997us/step - loss: 0.5074 - accuracy: 0.71
05
Epoch 232/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5073 - accuracy: 0.7206
Epoch 233/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5223 - accuracy: 0.6940
Epoch 234/400
11/11 [==============================] - 0s 997us/step - loss: 0.5164 - accuracy: 0.70
58
Epoch 235/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5176 - accuracy: 0.7151
Epoch 236/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5153 - accuracy: 0.7023
Epoch 237/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4935 - accuracy: 0.7320
Epoch 238/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5230 - accuracy: 0.7049
Epoch 239/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4999 - accuracy: 0.7090
Epoch 240/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5124 - accuracy: 0.7097
Epoch 241/400
11/11 [==============================] - 0s 997us/step - loss: 0.5136 - accuracy: 0.70
80
Epoch 242/400
11/11 [==============================] - 0s 940us/step - loss: 0.5135 - accuracy: 0.71
09
Epoch 243/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5279 - accuracy: 0.6960
Epoch 244/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5141 - accuracy: 0.7083
Epoch 245/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5072 - accuracy: 0.7051
Epoch 246/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5094 - accuracy: 0.7116
Epoch 247/400
11/11 [==============================] - 0s 2ms/step - loss: 0.5003 - accuracy: 0.7279
Epoch 248/400
11/11 [==============================] - 0s 984us/step - loss: 0.5145 - accuracy: 0.71
05
Epoch 249/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5105 - accuracy: 0.7151
Epoch 250/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5246 - accuracy: 0.6916
Epoch 251/400
11/11 [==============================] - 0s 997us/step - loss: 0.5238 - accuracy: 0.70
02
Epoch 252/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5070 - accuracy: 0.7155
Epoch 253/400
11/11 [==============================] - 0s 988us/step - loss: 0.5201 - accuracy: 0.69
49
Epoch 254/400
11/11 [==============================] - 0s 997us/step - loss: 0.5185 - accuracy: 0.70
46
Epoch 255/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5165 - accuracy: 0.7073
Epoch 256/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5141 - accuracy: 0.7055
Epoch 257/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5285 - accuracy: 0.7044
Epoch 258/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4968 - accuracy: 0.7236
Epoch 259/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5190 - accuracy: 0.7020
Epoch 260/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5154 - accuracy: 0.7068
Epoch 261/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5111 - accuracy: 0.7035
Epoch 262/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5202 - accuracy: 0.6984
Epoch 263/400
11/11 [==============================] - 0s 938us/step - loss: 0.5332 - accuracy: 0.69
96
Epoch 264/400
11/11 [==============================] - 0s 959us/step - loss: 0.5208 - accuracy: 0.70
81
Epoch 265/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5267 - accuracy: 0.6991
Epoch 266/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5044 - accuracy: 0.7101
Epoch 267/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5100 - accuracy: 0.7091
Epoch 268/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5230 - accuracy: 0.6977
Epoch 269/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5171 - accuracy: 0.7122
Epoch 270/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5203 - accuracy: 0.7075
Epoch 271/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5265 - accuracy: 0.7015
Epoch 272/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5139 - accuracy: 0.7110
Epoch 273/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5226 - accuracy: 0.6955
Epoch 274/400
11/11 [==============================] - 0s 898us/step - loss: 0.4919 - accuracy: 0.73
56
Epoch 275/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5145 - accuracy: 0.7115
Epoch 276/400
11/11 [==============================] - 0s 997us/step - loss: 0.5126 - accuracy: 0.70
91
Epoch 277/400
11/11 [==============================] - 0s 994us/step - loss: 0.5142 - accuracy: 0.71
38
Epoch 278/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5051 - accuracy: 0.7256
Epoch 279/400
11/11 [==============================] - 0s 997us/step - loss: 0.5115 - accuracy: 0.71
76
Epoch 280/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5235 - accuracy: 0.7065
Epoch 281/400
11/11 [==============================] - 0s 908us/step - loss: 0.5177 - accuracy: 0.71
58
Epoch 282/400
11/11 [==============================] - 0s 967us/step - loss: 0.5064 - accuracy: 0.71
02
Epoch 283/400
11/11 [==============================] - 0s 997us/step - loss: 0.5015 - accuracy: 0.71
70
Epoch 284/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5068 - accuracy: 0.7172
Epoch 285/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5210 - accuracy: 0.7078
Epoch 286/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5088 - accuracy: 0.7092
Epoch 287/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5066 - accuracy: 0.7121
Epoch 288/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5220 - accuracy: 0.7021
Epoch 289/400
11/11 [==============================] - 0s 997us/step - loss: 0.5211 - accuracy: 0.70
10
Epoch 290/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5237 - accuracy: 0.7063
Epoch 291/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5035 - accuracy: 0.7119
Epoch 292/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4977 - accuracy: 0.7186
Epoch 293/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5075 - accuracy: 0.7230
Epoch 294/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4975 - accuracy: 0.7189
Epoch 295/400
11/11 [==============================] - 0s 975us/step - loss: 0.5344 - accuracy: 0.69
50
Epoch 296/400
11/11 [==============================] - 0s 997us/step - loss: 0.5087 - accuracy: 0.70
94
Epoch 297/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5240 - accuracy: 0.7045
Epoch 298/400
11/11 [==============================] - 0s 945us/step - loss: 0.5192 - accuracy: 0.70
41
Epoch 299/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5288 - accuracy: 0.6968
Epoch 300/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5045 - accuracy: 0.7269
Epoch 301/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5276 - accuracy: 0.7022
Epoch 302/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5166 - accuracy: 0.7050
Epoch 303/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5111 - accuracy: 0.7160
Epoch 304/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5041 - accuracy: 0.7154
Epoch 305/400
11/11 [==============================] - 0s 995us/step - loss: 0.5320 - accuracy: 0.67
45
Epoch 306/400
11/11 [==============================] - 0s 998us/step - loss: 0.5326 - accuracy: 0.69
48
Epoch 307/400
11/11 [==============================] - 0s 994us/step - loss: 0.5259 - accuracy: 0.70
20
Epoch 308/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5203 - accuracy: 0.7141
Epoch 309/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4959 - accuracy: 0.7226
Epoch 310/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5271 - accuracy: 0.7021
Epoch 311/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5166 - accuracy: 0.7102
Epoch 312/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5000 - accuracy: 0.7217
Epoch 313/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5079 - accuracy: 0.7081
Epoch 314/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5113 - accuracy: 0.7070
Epoch 315/400
11/11 [==============================] - 0s 992us/step - loss: 0.5106 - accuracy: 0.71
62
Epoch 316/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5238 - accuracy: 0.6978
Epoch 317/400
11/11 [==============================] - 0s 996us/step - loss: 0.5028 - accuracy: 0.71
65
Epoch 318/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5543 - accuracy: 0.6758
Epoch 319/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5195 - accuracy: 0.6962
Epoch 320/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5191 - accuracy: 0.7108
Epoch 321/400
11/11 [==============================] - 0s 997us/step - loss: 0.5125 - accuracy: 0.70
84
Epoch 322/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5276 - accuracy: 0.7087
Epoch 323/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5193 - accuracy: 0.7042
Epoch 324/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5071 - accuracy: 0.7110
Epoch 325/400
11/11 [==============================] - 0s 998us/step - loss: 0.5081 - accuracy: 0.71
13
Epoch 326/400
11/11 [==============================] - 0s 894us/step - loss: 0.5180 - accuracy: 0.70
56
Epoch 327/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4989 - accuracy: 0.7100
Epoch 328/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5297 - accuracy: 0.7027
Epoch 329/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5163 - accuracy: 0.7070
Epoch 330/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4975 - accuracy: 0.7285
Epoch 331/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5248 - accuracy: 0.7074
Epoch 332/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5225 - accuracy: 0.7046
Epoch 333/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5130 - accuracy: 0.7152
Epoch 334/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5046 - accuracy: 0.7087
Epoch 335/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5141 - accuracy: 0.7093
Epoch 336/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4917 - accuracy: 0.7296
Epoch 337/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5159 - accuracy: 0.7128
Epoch 338/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5218 - accuracy: 0.7083
Epoch 339/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5254 - accuracy: 0.7004
Epoch 340/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5170 - accuracy: 0.6991
Epoch 341/400
11/11 [==============================] - 0s 997us/step - loss: 0.5175 - accuracy: 0.69
31
Epoch 342/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5252 - accuracy: 0.6884
Epoch 343/400
11/11 [==============================] - 0s 961us/step - loss: 0.5069 - accuracy: 0.71
75
Epoch 344/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5152 - accuracy: 0.7093
Epoch 345/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5063 - accuracy: 0.7162
Epoch 346/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5192 - accuracy: 0.6957
Epoch 347/400
11/11 [==============================] - 0s 997us/step - loss: 0.5135 - accuracy: 0.70
98
Epoch 348/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4967 - accuracy: 0.7320
Epoch 349/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4981 - accuracy: 0.7186
Epoch 350/400
11/11 [==============================] - 0s 957us/step - loss: 0.5095 - accuracy: 0.71
43
Epoch 351/400
11/11 [==============================] - 0s 997us/step - loss: 0.5176 - accuracy: 0.70
79
Epoch 352/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5173 - accuracy: 0.7043
Epoch 353/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5254 - accuracy: 0.7011
Epoch 354/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5307 - accuracy: 0.6889
Epoch 355/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4978 - accuracy: 0.7248
Epoch 356/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5152 - accuracy: 0.7007
Epoch 357/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5096 - accuracy: 0.7111
Epoch 358/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5112 - accuracy: 0.7080
Epoch 359/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5188 - accuracy: 0.7054
Epoch 360/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4908 - accuracy: 0.7185
Epoch 361/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5017 - accuracy: 0.7142
Epoch 362/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5240 - accuracy: 0.6988
Epoch 363/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5014 - accuracy: 0.7185
Epoch 364/400
11/11 [==============================] - 0s 958us/step - loss: 0.5097 - accuracy: 0.70
61
Epoch 365/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4989 - accuracy: 0.7236
Epoch 366/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5086 - accuracy: 0.7201
Epoch 367/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5104 - accuracy: 0.6971
Epoch 368/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4999 - accuracy: 0.7217
Epoch 369/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5211 - accuracy: 0.7071
Epoch 370/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5174 - accuracy: 0.7026
Epoch 371/400
11/11 [==============================] - 0s 997us/step - loss: 0.5089 - accuracy: 0.71
85
Epoch 372/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4922 - accuracy: 0.7245
Epoch 373/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5213 - accuracy: 0.7106
Epoch 374/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5138 - accuracy: 0.7127
Epoch 375/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4994 - accuracy: 0.7158
Epoch 376/400
11/11 [==============================] - 0s 997us/step - loss: 0.5004 - accuracy: 0.71
78
Epoch 377/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5227 - accuracy: 0.7011
Epoch 378/400
11/11 [==============================] - 0s 997us/step - loss: 0.5311 - accuracy: 0.69
81
Epoch 379/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5169 - accuracy: 0.7105
Epoch 380/400
11/11 [==============================] - 0s 1ms/step - loss: 0.4969 - accuracy: 0.7251
Epoch 381/400
11/11 [==============================] - 0s 974us/step - loss: 0.5125 - accuracy: 0.70
83
Epoch 382/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5147 - accuracy: 0.6989
Epoch 383/400
11/11 [==============================] - 0s 997us/step - loss: 0.5275 - accuracy: 0.71
05
Epoch 384/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5078 - accuracy: 0.7111
Epoch 385/400
11/11 [==============================] - 0s 994us/step - loss: 0.5152 - accuracy: 0.71
33
Epoch 386/400
11/11 [==============================] - 0s 997us/step - loss: 0.5114 - accuracy: 0.71
31
Epoch 387/400
11/11 [==============================] - 0s 897us/step - loss: 0.5187 - accuracy: 0.69
68
Epoch 388/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5126 - accuracy: 0.7111
Epoch 389/400
11/11 [==============================] - 0s 956us/step - loss: 0.5090 - accuracy: 0.71
08
Epoch 390/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5158 - accuracy: 0.7055
Epoch 391/400
11/11 [==============================] - 0s 900us/step - loss: 0.5022 - accuracy: 0.71
26
Epoch 392/400
11/11 [==============================] - 0s 997us/step - loss: 0.5250 - accuracy: 0.70
74
Epoch 393/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5379 - accuracy: 0.6842
Epoch 394/400
11/11 [==============================] - 0s 999us/step - loss: 0.5183 - accuracy: 0.69
91
Epoch 395/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5250 - accuracy: 0.7051
Epoch 396/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5108 - accuracy: 0.7074
Epoch 397/400
11/11 [==============================] - 0s 1ms/step - loss: 0.5023 - accuracy: 0.7171
Epoch 398/400
11/11 [==============================] - 0s 997us/step - loss: 0.4859 - accuracy: 0.73
38
Epoch 399/400
11/11 [==============================] - 0s 940us/step - loss: 0.5242 - accuracy: 0.70
04
Epoch 400/400
11/11 [==============================] - 0s 898us/step - loss: 0.4900 - accuracy: 0.71
78
```

In [388…

```
historyDF = pd.DataFrame(history.history)
historyDF['epoch']=historyDF.index+1
```

In [391…

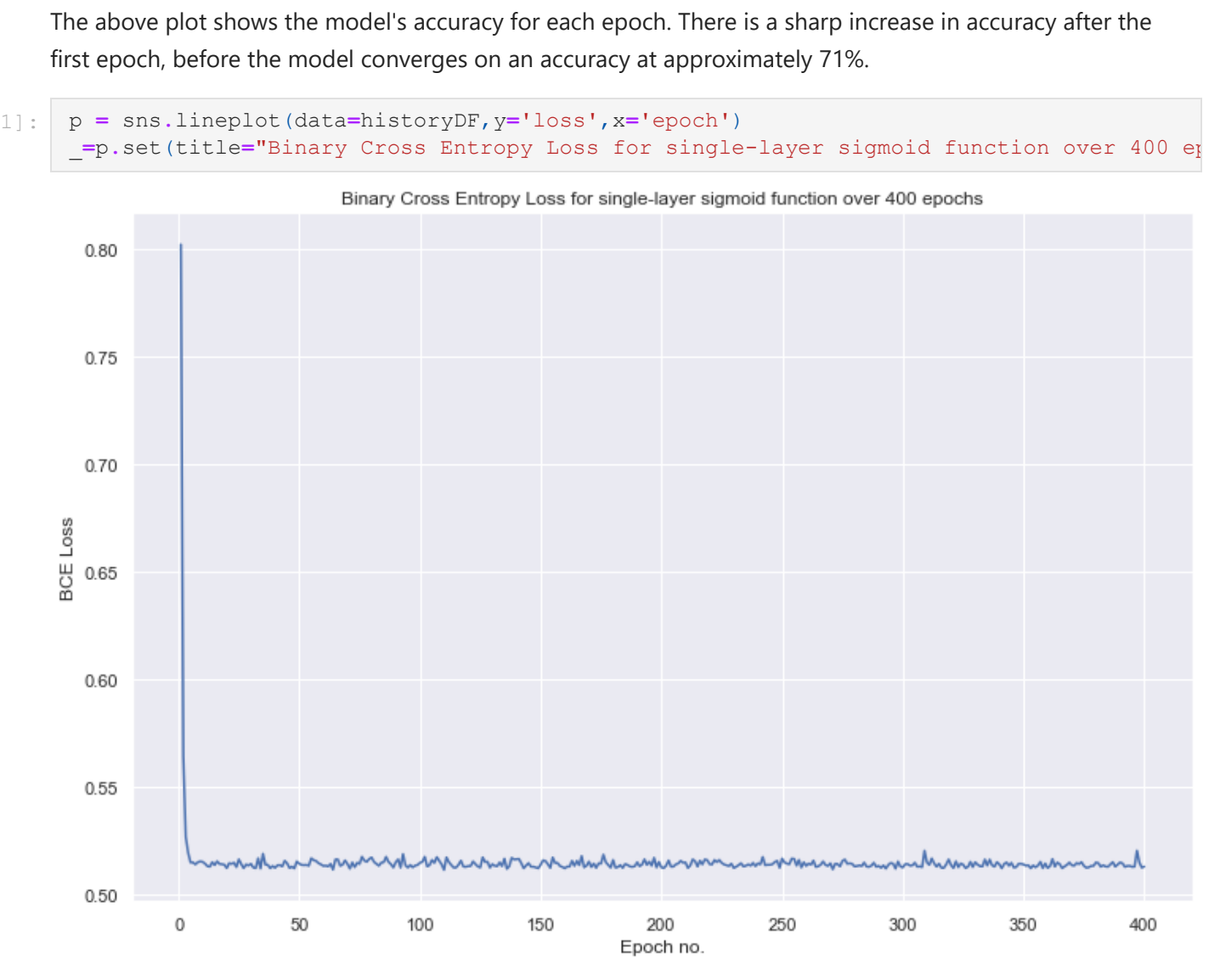
```
p = sns.lineplot(data=historyDF,y='accuracy',x='epoch')
_=p.set(title="Model Accuracy for single-layer sigmoid function over 400 epochs",ylabe
```



The above plot shows the model's accuracy for each epoch. There is a sharp increase in accuracy after the first epoch, before the model converges on an accuracy at approximately 71%.

In [11]:

```
p = sns.lineplot(data=historyDF,y='loss',x='epoch')
_=p.set(title="Binary Cross Entropy Loss for single-layer sigmoid function over 400 ep
```



The above plot shows the model's binary cross entropy loss for each epoch. There is a sharp drop in the loss function after the first epoch, before the model begins to converge on a binary cross entropy loss of approximately 0.52.

In [12]:

```
print('Final Accuracy: ',str(history.history['accuracy'][-1]))
```

```
Final Accuracy:  0.7077259421348572
```

In [392…

```
x1list = np.linspace(np.min(X[:,0])-2, np.max(X[:,0])+2, 50) # Define 50 points on the
x2list = np.linspace(np.min(X[:,1])-2, np.max(X[:,1])+2, 50) # Define 50 points on the
x1s,x2s=np.meshgrid(x1list,x2list)

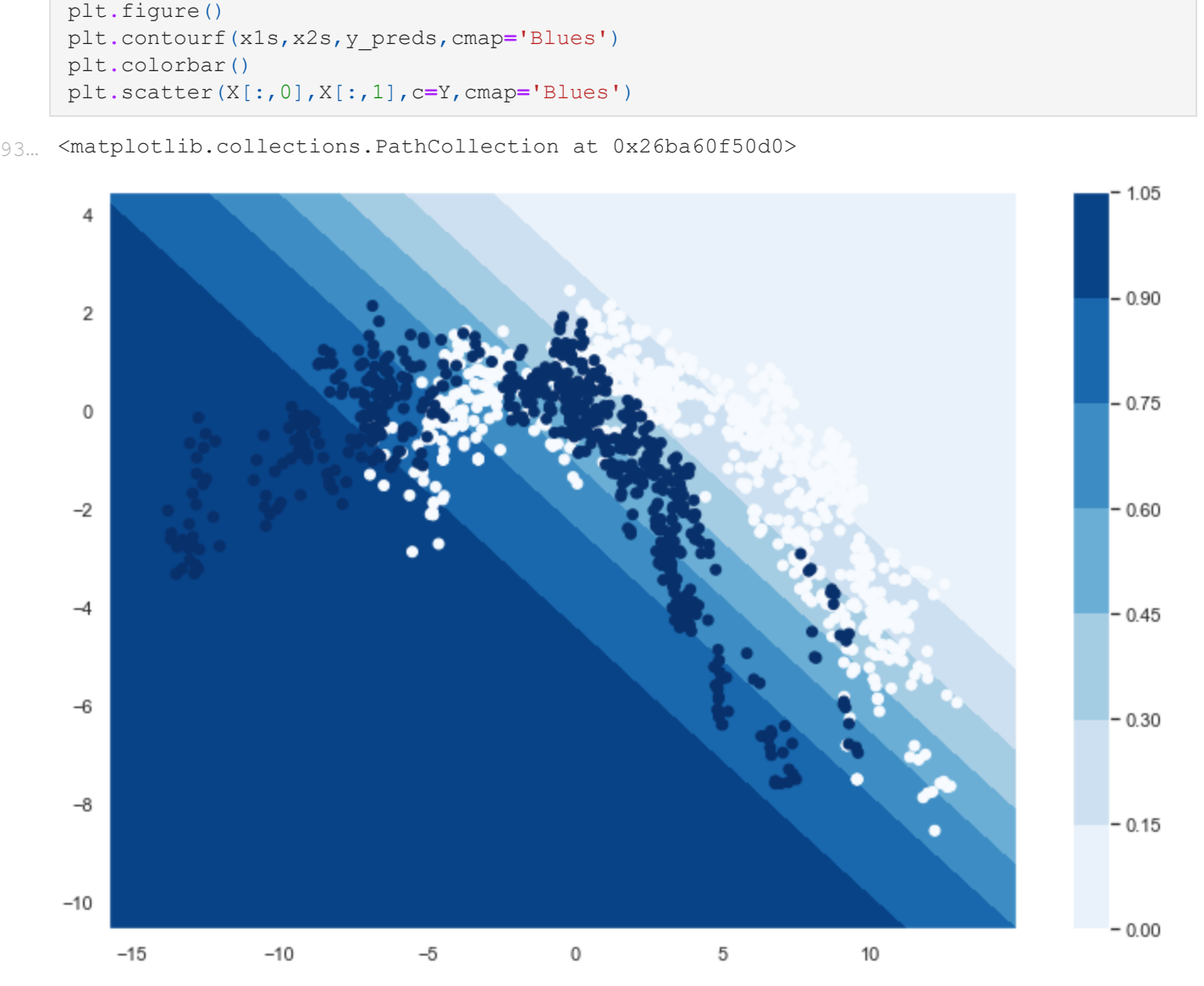
x1,x2=x1s.flatten(),x2s.flatten()
grid = np.vstack((x1,x2)).T
y_pred = model.predict(grid)
y_preds = y_pred.reshape(x1s.shape)
```

In [393…

```
from matplotlib.colors import Colormap
plt.figure()
plt.contourf(x1s,x2s,y_preds,cmap='Blues')
plt.colorbar()
plt.scatter(X[:,0],X[:,1],c=Y,cmap='Blues')
```

Out[393…

```
<matplotlib.collections.PathCollection at 0x26ba60f50d0>
```



Above is the contour plot for logistic regression of the 2 variables. Visually, the contour misclassifies many points, with many white points (class=0) falling in the blue zone.

In [394…

```
from tensorflow.keras.utils import to_categorical
Y_c=to_categorical(Y,2)
```

In [396…

```
opt = tf.keras.optimizers.SGD(learning_rate=0.15)
model = keras.Sequential()
model.add(Dense(8, batch_input_shape=(None, 2),activation='sigmoid'))
model.add(Dense(2,batch_input_shape=(None,8),activation='softmax'))
model.compile(opt,loss='categorical_crossentropy',metrics=['accuracy'])
history=model.fit(X,Y_c,batch_size=128,epochs=400)
```

```
Epoch 1/400
11/11 [==============================] - 9s 3ms/step - loss: 0.8124 - accuracy: 0.5496
Epoch 2/400
11/11 [==============================] - 0s 4ms/step - loss: 0.6585 - accuracy: 0.6095
Epoch 3/400
11/11 [==============================] - 0s 4ms/step - loss: 0.6151 - accuracy: 0.6220
Epoch 4/400
11/11 [==============================] - 0s 4ms/step - loss: 0.5918 - accuracy: 0.6229
Epoch 5/400
11/11 [==============================] - 0s 6ms/step - loss: 0.5725 - accuracy: 0.6370
Epoch 6/400
11/11 [==============================] - 0s 3ms/step - loss: 0.5560 - accuracy: 0.6429
Epoch 7/400
11/11 [==============================] - 0s 2ms/step - loss: 0.5438 - accuracy: 0.6831
Epoch 8/400
11/11 [==============================] - 0s 3ms/step - loss: 0.5326 - accuracy: 0.7114
Epoch 9/400
11/11 [==============================] - 0s 3ms/step - loss: 0.5258 - accuracy: 0.6904
Epoch 10/400
11/11 [==============================] - 0s 3ms/step - loss: 0.5162 - accuracy: 0.7048
Epoch 11/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4936 - accuracy: 0.7373
Epoch 12/400
11/11 [==============================] - 0s 3ms/step - loss: 0.5150 - accuracy: 0.7248
Epoch 13/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4976 - accuracy: 0.7338
Epoch 14/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4899 - accuracy: 0.7454
Epoch 15/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4815 - accuracy: 0.7423
Epoch 16/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4847 - accuracy: 0.7488
Epoch 17/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4852 - accuracy: 0.7481
Epoch 18/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4767 - accuracy: 0.7459
Epoch 19/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4640 - accuracy: 0.7620
Epoch 20/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4635 - accuracy: 0.7519
Epoch 21/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4742 - accuracy: 0.7466
Epoch 22/400
11/11 [==============================] - 0s 3ms/step - loss: 0.4703 - accuracy: 0.7540
Epoch 23/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4602 - accuracy: 0.7605
Epoch 24/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4497 - accuracy: 0.7642
Epoch 25/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4361 - accuracy: 0.7911
Epoch 26/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4463 - accuracy: 0.7674
Epoch 27/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4412 - accuracy: 0.7727
Epoch 28/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4375 - accuracy: 0.7711
Epoch 29/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4485 - accuracy: 0.7662
Epoch 30/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4503 - accuracy: 0.7574
Epoch 31/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4340 - accuracy: 0.7753
Epoch 32/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4333 - accuracy: 0.7825
Epoch 33/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4242 - accuracy: 0.7826
Epoch 34/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4218 - accuracy: 0.7786
Epoch 35/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4168 - accuracy: 0.7934
Epoch 36/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4208 - accuracy: 0.7843
Epoch 37/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4194 - accuracy: 0.7871
Epoch 38/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4138 - accuracy: 0.7879
Epoch 39/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4264 - accuracy: 0.7811
Epoch 40/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4152 - accuracy: 0.8015
Epoch 41/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3917 - accuracy: 0.8110
Epoch 42/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4159 - accuracy: 0.7986
Epoch 43/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4108 - accuracy: 0.7870
Epoch 44/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3993 - accuracy: 0.8094
Epoch 45/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4108 - accuracy: 0.7920
Epoch 46/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4011 - accuracy: 0.7906
Epoch 47/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4040 - accuracy: 0.7987
Epoch 48/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4103 - accuracy: 0.7936
Epoch 49/400
11/11 [==============================] - 0s 2ms/step - loss: 0.4041 - accuracy: 0.7987
Epoch 50/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3816 - accuracy: 0.8185
Epoch 51/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3984 - accuracy: 0.7902
Epoch 52/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3968 - accuracy: 0.7993
Epoch 53/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3890 - accuracy: 0.8099
Epoch 54/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3847 - accuracy: 0.8107
Epoch 55/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3919 - accuracy: 0.8013
Epoch 56/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3849 - accuracy: 0.8113
Epoch 57/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3785 - accuracy: 0.8190
Epoch 58/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3937 - accuracy: 0.8175
Epoch 59/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3872 - accuracy: 0.7981
Epoch 60/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3826 - accuracy: 0.8027
Epoch 61/400
```

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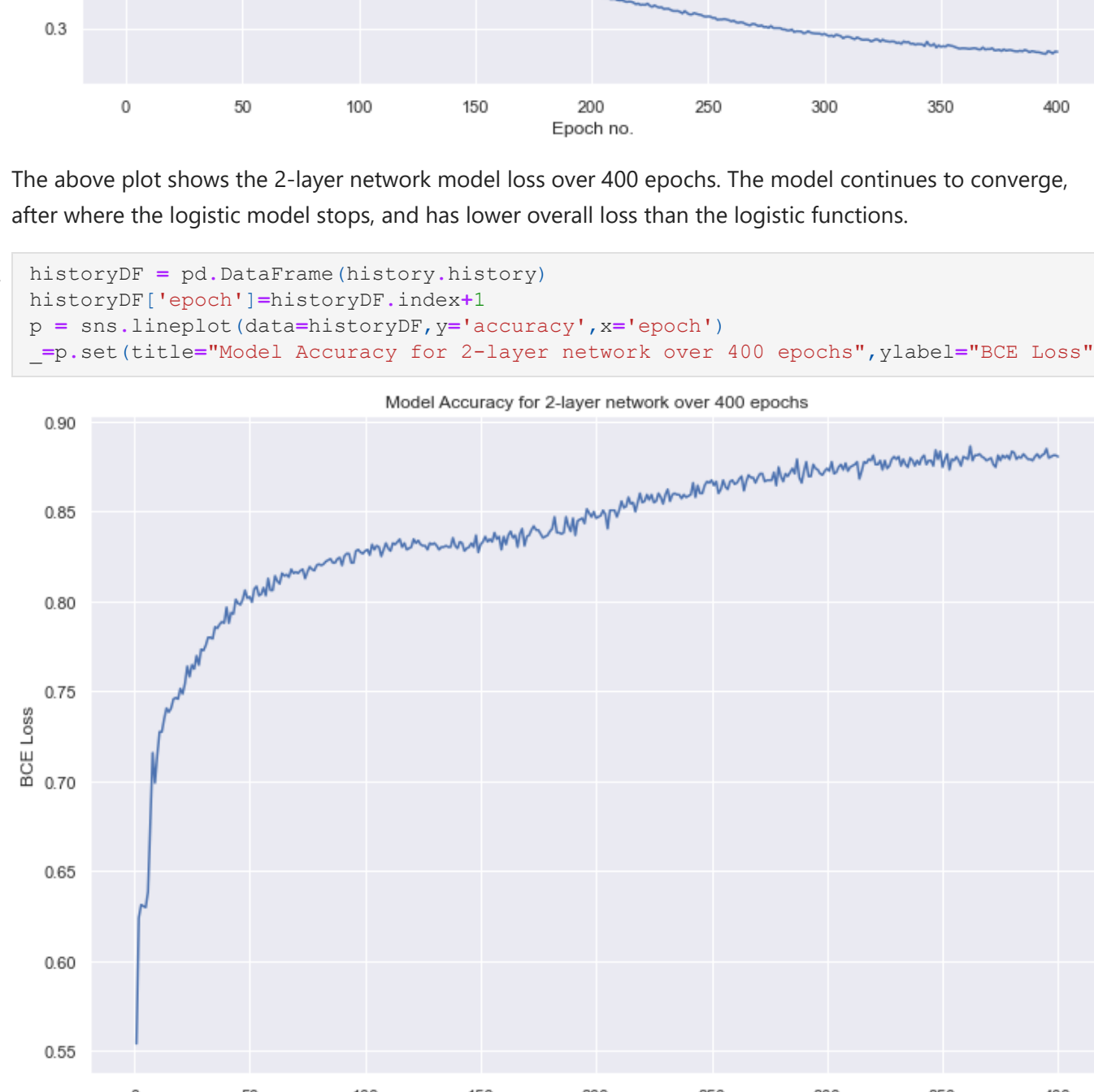
11/11 [==============================] - 0s 2ms/step - loss: 0.4061 - accuracy: 0.7973
Epoch 62/400
11/11 [==============================] - 0s 4ms/step - loss: 0.3717 - accuracy: 0.8193
Epoch 63/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3767 - accuracy: 0.8295
Epoch 64/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3755 - accuracy: 0.8148
Epoch 65/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3868 - accuracy: 0.8150
Epoch 66/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3713 - accuracy: 0.8235
Epoch 67/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3701 - accuracy: 0.8215
Epoch 68/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3967 - accuracy: 0.8086
Epoch 69/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3764 - accuracy: 0.8260
Epoch 70/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3651 - accuracy: 0.8248
Epoch 71/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3726 - accuracy: 0.8217
Epoch 72/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3877 - accuracy: 0.8073
Epoch 73/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3733 - accuracy: 0.8209
Epoch 74/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3795 - accuracy: 0.8125
Epoch 75/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3717 - accuracy: 0.8207
Epoch 76/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3870 - accuracy: 0.8089
Epoch 77/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3643 - accuracy: 0.8123
Epoch 78/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3644 - accuracy: 0.8263
Epoch 79/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3658 - accuracy: 0.8215
Epoch 80/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3594 - accuracy: 0.8293
Epoch 81/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3655 - accuracy: 0.8240
Epoch 82/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3684 - accuracy: 0.8221
Epoch 83/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3466 - accuracy: 0.8370
Epoch 84/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3701 - accuracy: 0.8174
Epoch 85/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3605 - accuracy: 0.8316
Epoch 86/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3538 - accuracy: 0.8305
Epoch 87/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3662 - accuracy: 0.8199
Epoch 88/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3600 - accuracy: 0.8300
Epoch 89/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3689 - accuracy: 0.8249
Epoch 90/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3756 - accuracy: 0.8085
Epoch 91/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3517 - accuracy: 0.8336
Epoch 92/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3629 - accuracy: 0.8219
Epoch 93/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3512 - accuracy: 0.8368
Epoch 94/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3588 - accuracy: 0.8178
Epoch 95/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3591 - accuracy: 0.8250
Epoch 96/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3581 - accuracy: 0.8340
Epoch 97/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3691 - accuracy: 0.8229
Epoch 98/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3612 - accuracy: 0.8266
Epoch 99/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3510 - accuracy: 0.8273
Epoch 100/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3568 - accuracy: 0.8273
Epoch 101/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3459 - accuracy: 0.8379
Epoch 102/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3607 - accuracy: 0.8205
Epoch 103/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3544 - accuracy: 0.8339
Epoch 104/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3525 - accuracy: 0.8223
Epoch 105/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3485 - accuracy: 0.8290
Epoch 106/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3567 - accuracy: 0.8254
Epoch 107/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3619 - accuracy: 0.8147
Epoch 108/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3511 - accuracy: 0.8294
Epoch 109/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3466 - accuracy: 0.8398
Epoch 110/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3514 - accuracy: 0.8290
Epoch 111/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3229 - accuracy: 0.8472
Epoch 112/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3604 - accuracy: 0.8320
Epoch 113/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3716 - accuracy: 0.8254
Epoch 114/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3530 - accuracy: 0.8398
Epoch 115/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3596 - accuracy: 0.8274
Epoch 116/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3532 - accuracy: 0.8285
Epoch 117/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3611 - accuracy: 0.8289
Epoch 118/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3541 - accuracy: 0.8236
Epoch 119/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3409 - accuracy: 0.8346
Epoch 120/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3482 - accuracy: 0.8305
Epoch 121/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3738 - accuracy: 0.8066
Epoch 122/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3566 - accuracy: 0.8246
Epoch 123/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3369 - accuracy: 0.8356
Epoch 124/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3604 - accuracy: 0.8245
Epoch 125/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3613 - accuracy: 0.8265
Epoch 126/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3545 - accuracy: 0.8312
Epoch 127/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3460 - accuracy: 0.8337
Epoch 128/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3554 - accuracy: 0.8238
Epoch 129/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3418 - accuracy: 0.8293
Epoch 130/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3318 - accuracy: 0.8390
Epoch 131/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3407 - accuracy: 0.8398
Epoch 132/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3451 - accuracy: 0.8244
Epoch 133/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3430 - accuracy: 0.8449
Epoch 134/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3591 - accuracy: 0.8272
Epoch 135/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3624 - accuracy: 0.8197
Epoch 136/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3460 - accuracy: 0.8204
Epoch 137/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3416 - accuracy: 0.8266
Epoch 138/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3466 - accuracy: 0.8352
Epoch 139/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3349 - accuracy: 0.8374
Epoch 140/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3462 - accuracy: 0.8230
Epoch 141/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3373 - accuracy: 0.8371
Epoch 142/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3494 - accuracy: 0.8361
Epoch 143/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3435 - accuracy: 0.8310
Epoch 144/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3380 - accuracy: 0.8282
Epoch 145/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3323 - accuracy: 0.8446
Epoch 146/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3493 - accuracy: 0.8274
Epoch 147/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3321 - accuracy: 0.8359
Epoch 148/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3563 - accuracy: 0.8166
Epoch 149/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3326 - accuracy: 0.8370
Epoch 150/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3394 - accuracy: 0.8327
Epoch 151/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3143 - accuracy: 0.8562
Epoch 152/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3361 - accuracy: 0.8363
Epoch 153/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3428 - accuracy: 0.8427
Epoch 154/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3420 - accuracy: 0.8327
Epoch 155/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3371 - accuracy: 0.8361
Epoch 156/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3322 - accuracy: 0.8387
Epoch 157/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3273 - accuracy: 0.8341
Epoch 158/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3315 - accuracy: 0.8409
Epoch 159/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3261 - accuracy: 0.8380
Epoch 160/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3481 - accuracy: 0.8236
Epoch 161/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3378 - accuracy: 0.8338
Epoch 162/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3490 - accuracy: 0.8312
Epoch 163/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3401 - accuracy: 0.8347
Epoch 164/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3487 - accuracy: 0.8326
Epoch 165/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3317 - accuracy: 0.8334
Epoch 166/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3497 - accuracy: 0.8140
Epoch 167/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3526 - accuracy: 0.8260
Epoch 168/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3373 - accuracy: 0.8374
Epoch 169/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3416 - accuracy: 0.8275
Epoch 170/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3311 - accuracy: 0.8317
Epoch 171/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3242 - accuracy: 0.8407
Epoch 172/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3297 - accuracy: 0.8466
Epoch 173/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3341 - accuracy: 0.8450
Epoch 174/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3371 - accuracy: 0.8346
Epoch 175/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3225 - accuracy: 0.8497
Epoch 176/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3295 - accuracy: 0.8430
Epoch 177/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3250 - accuracy: 0.8407
Epoch 178/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3310 - accuracy: 0.8345
Epoch 179/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3311 - accuracy: 0.8423
Epoch 180/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3334 - accuracy: 0.8385
Epoch 181/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3352 - accuracy: 0.8433
Epoch 182/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3155 - accuracy: 0.8553
Epoch 183/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3327 - accuracy: 0.8304
Epoch 184/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3279 - accuracy: 0.8386
Epoch 185/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3257 - accuracy: 0.8376
Epoch 186/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3167 - accuracy: 0.8436
Epoch 187/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3478 - accuracy: 0.8357
Epoch 188/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3395 - accuracy: 0.8382
Epoch 189/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3144 - accuracy: 0.8455
Epoch 190/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3365 - accuracy: 0.8393
Epoch 191/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3375 - accuracy: 0.8295
Epoch 192/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3230 - accuracy: 0.8489
Epoch 193/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3294 - accuracy: 0.8536
Epoch 194/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3308 - accuracy: 0.8513
Epoch 195/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3360 - accuracy: 0.8425
Epoch 196/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3189 - accuracy: 0.8646
Epoch 197/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3150 - accuracy: 0.8579
Epoch 198/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3090 - accuracy: 0.8564
Epoch 199/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3234 - accuracy: 0.8580
Epoch 200/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3195 - accuracy: 0.8540
Epoch 201/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3129 - accuracy: 0.8534
Epoch 202/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3261 - accuracy: 0.8516
Epoch 203/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3264 - accuracy: 0.8561
Epoch 204/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3244 - accuracy: 0.8515
Epoch 205/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3171 - accuracy: 0.8475
Epoch 206/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3148 - accuracy: 0.8612
Epoch 207/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3204 - accuracy: 0.8550
Epoch 208/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3143 - accuracy: 0.8636
Epoch 209/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3152 - accuracy: 0.8473
Epoch 210/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3230 - accuracy: 0.8595
Epoch 211/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3175 - accuracy: 0.8602
Epoch 212/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3164 - accuracy: 0.8547
Epoch 213/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3227 - accuracy: 0.8598
Epoch 214/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3084 - accuracy: 0.8610
Epoch 215/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3323 - accuracy: 0.8482
Epoch 216/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3156 - accuracy: 0.8535
Epoch 217/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3092 - accuracy: 0.8556
Epoch 218/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3254 - accuracy: 0.8587
Epoch 219/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3177 - accuracy: 0.8667
Epoch 220/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3309 - accuracy: 0.8426
Epoch 221/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3327 - accuracy: 0.8433
Epoch 222/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3199 - accuracy: 0.8584
Epoch 223/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2922 - accuracy: 0.8739
Epoch 224/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3200 - accuracy: 0.8593
Epoch 225/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3198 - accuracy: 0.8520
Epoch 226/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3167 - accuracy: 0.8624
Epoch 227/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3080 - accuracy: 0.8654
Epoch 228/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3121 - accuracy: 0.8531
Epoch 229/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3033 - accuracy: 0.8653
Epoch 230/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3105 - accuracy: 0.8620
Epoch 231/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3112 - accuracy: 0.8654
Epoch 232/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3219 - accuracy: 0.8576
Epoch 233/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3129 - accuracy: 0.8589
Epoch 234/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3205 - accuracy: 0.8527
Epoch 235/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3028 - accuracy: 0.8618
Epoch 236/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3145 - accuracy: 0.8612
Epoch 237/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3067 - accuracy: 0.8605
Epoch 238/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3148 - accuracy: 0.8570
Epoch 239/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3050 - accuracy: 0.8682
Epoch 240/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3095 - accuracy: 0.8610
Epoch 241/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3063 - accuracy: 0.8709
Epoch 242/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3218 - accuracy: 0.8595
Epoch 243/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2952 - accuracy: 0.8722
Epoch 244/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3281 - accuracy: 0.8557
Epoch 245/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2994 - accuracy: 0.8650
Epoch 246/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3042 - accuracy: 0.8611
Epoch 247/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3139 - accuracy: 0.8645
Epoch 248/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3085 - accuracy: 0.8647
Epoch 249/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3040 - accuracy: 0.8608
Epoch 250/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3165 - accuracy: 0.8683
Epoch 251/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3030 - accuracy: 0.8698
Epoch 252/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3045 - accuracy: 0.8740
Epoch 253/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3088 - accuracy: 0.8611
Epoch 254/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3106 - accuracy: 0.8574
Epoch 255/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2921 - accuracy: 0.8767
Epoch 256/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2989 - accuracy: 0.8673
Epoch 257/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3177 - accuracy: 0.8591
Epoch 258/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2983 - accuracy: 0.8772
Epoch 259/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3180 - accuracy: 0.8606
Epoch 260/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2971 - accuracy: 0.8766
Epoch 261/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3040 - accuracy: 0.8649
Epoch 262/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3076 - accuracy: 0.8684
Epoch 263/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3012 - accuracy: 0.8785
Epoch 264/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3034 - accuracy: 0.8563
Epoch 265/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2832 - accuracy: 0.8812
Epoch 266/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2933 - accuracy: 0.8787
Epoch 267/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3041 - accuracy: 0.8685
Epoch 268/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3039 - accuracy: 0.8699
Epoch 269/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2945 - accuracy: 0.8739
Epoch 270/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2950 - accuracy: 0.8742
Epoch 271/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3065 - accuracy: 0.8669
Epoch 272/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3176 - accuracy: 0.8597
Epoch 273/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2888 - accuracy: 0.8823
Epoch 274/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3096 - accuracy: 0.8547
Epoch 275/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3060 - accuracy: 0.8608
Epoch 276/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3016 - accuracy: 0.8737
Epoch 277/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3046 - accuracy: 0.8687
Epoch 278/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2893 - accuracy: 0.8738
Epoch 279/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2983 - accuracy: 0.8762
Epoch 280/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3057 - accuracy: 0.8644
Epoch 281/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3069 - accuracy: 0.8617
Epoch 282/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3010 - accuracy: 0.8768
Epoch 283/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3076 - accuracy: 0.8589
Epoch 284/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3093 - accuracy: 0.8649
Epoch 285/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3139 - accuracy: 0.8630
Epoch 286/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2876 - accuracy: 0.8787
Epoch 287/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2859 - accuracy: 0.8860
Epoch 288/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2958 - accuracy: 0.8697
Epoch 289/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3047 - accuracy: 0.8625
Epoch 290/400
11/11 [==============================] - 0s 3ms/step - loss: 0.3071 - accuracy: 0.8656
Epoch 291/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2902 - accuracy: 0.8800
Epoch 292/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3075 - accuracy: 0.8512
Epoch 293/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2878 - accuracy: 0.8722
Epoch 294/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2937 - accuracy: 0.8804
Epoch 295/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3006 - accuracy: 0.8676
Epoch 296/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3004 - accuracy: 0.8668
Epoch 297/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3028 - accuracy: 0.8679
Epoch 298/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2847 - accuracy: 0.8825
Epoch 299/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2977 - accuracy: 0.8776
Epoch 300/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3028 - accuracy: 0.8687
Epoch 301/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2937 - accuracy: 0.8704
Epoch 302/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2797 - accuracy: 0.8721
Epoch 303/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2893 - accuracy: 0.8681
Epoch 304/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3058 - accuracy: 0.8656
Epoch 305/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2942 - accuracy: 0.8769
Epoch 306/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3074 - accuracy: 0.8740
Epoch 307/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2999 - accuracy: 0.8656
Epoch 308/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2969 - accuracy: 0.8765
Epoch 309/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3020 - accuracy: 0.8610
Epoch 310/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3053 - accuracy: 0.8670
Epoch 311/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2953 - accuracy: 0.8682
Epoch 312/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2959 - accuracy: 0.8766
Epoch 313/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2826 - accuracy: 0.8866
Epoch 314/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2930 - accuracy: 0.8681
Epoch 315/400
11/11 [==============================] - 0s 1ms/step - loss: 0.3079 - accuracy: 0.8607
Epoch 316/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2880 - accuracy: 0.8786
Epoch 317/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2990 - accuracy: 0.8715
Epoch 318/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2823 - accuracy: 0.8874
Epoch 319/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2886 - accuracy: 0.8784
Epoch 320/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2893 - accuracy: 0.8792
Epoch 321/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2942 - accuracy: 0.8786
Epoch 322/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2904 - accuracy: 0.8741
Epoch 323/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3068 - accuracy: 0.8700
Epoch 324/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3071 - accuracy: 0.8581
Epoch 325/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3048 - accuracy: 0.8708
Epoch 326/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2988 - accuracy: 0.8765
Epoch 327/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3017 - accuracy: 0.8717
Epoch 328/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2903 - accuracy: 0.8766
Epoch 329/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2960 - accuracy: 0.8817
Epoch 330/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3039 - accuracy: 0.8640
Epoch 331/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2901 - accuracy: 0.8756
Epoch 332/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2882 - accuracy: 0.8742
Epoch 333/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2873 - accuracy: 0.8788
Epoch 334/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2825 - accuracy: 0.8816
Epoch 335/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2847 - accuracy: 0.8790
Epoch 336/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2916 - accuracy: 0.8802
Epoch 337/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2925 - accuracy: 0.8752
Epoch 338/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2850 - accuracy: 0.8869
Epoch 339/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2929 - accuracy: 0.8757
Epoch 340/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3030 - accuracy: 0.8635
Epoch 341/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2913 - accuracy: 0.8728
Epoch 342/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2780 - accuracy: 0.8830
Epoch 343/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2875 - accuracy: 0.8681
Epoch 344/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2859 - accuracy: 0.8760
Epoch 345/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2828 - accuracy: 0.8845
Epoch 346/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2653 - accuracy: 0.8841
Epoch 347/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2863 - accuracy: 0.8906
Epoch 348/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2777 - accuracy: 0.8782
Epoch 349/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2826 - accuracy: 0.8839
Epoch 350/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2890 - accuracy: 0.8720
Epoch 351/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2833 - accuracy: 0.8895
Epoch 352/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2853 - accuracy: 0.8779
Epoch 353/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2893 - accuracy: 0.8714
Epoch 354/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2844 - accuracy: 0.8827
Epoch 355/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2973 - accuracy: 0.8711
Epoch 356/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2907 - accuracy: 0.8739
Epoch 357/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2692 - accuracy: 0.8885
Epoch 358/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2886 - accuracy: 0.8753
Epoch 359/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2837 - accuracy: 0.8758
Epoch 360/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2729 - accuracy: 0.8868
Epoch 361/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2956 - accuracy: 0.8733
Epoch 362/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2827 - accuracy: 0.8861
Epoch 363/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2700 - accuracy: 0.8858
Epoch 364/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2863 - accuracy: 0.8822
Epoch 365/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2871 - accuracy: 0.8784
Epoch 366/400
11/11 [==============================] - 0s 2ms/step - loss: 0.3020 - accuracy: 0.8652
Epoch 367/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2936 - accuracy: 0.8829
Epoch 368/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2850 - accuracy: 0.8846
Epoch 369/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2901 - accuracy: 0.8738
Epoch 370/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2776 - accuracy: 0.8803
Epoch 371/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2833 - accuracy: 0.8827
Epoch 372/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2825 - accuracy: 0.8834
Epoch 373/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2630 - accuracy: 0.8909
Epoch 374/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2599 - accuracy: 0.8975
Epoch 375/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2790 - accuracy: 0.8818
Epoch 376/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2856 - accuracy: 0.8746
Epoch 377/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2679 - accuracy: 0.8905
Epoch 378/400
11/11 [==============================] - 0s 3ms/step - loss: 0.2819 - accuracy: 0.8892
Epoch 379/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2902 - accuracy: 0.8756
Epoch 380/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2729 - accuracy: 0.8931
Epoch 381/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2896 - accuracy: 0.8716
Epoch 382/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2839 - accuracy: 0.8801
Epoch 383/400
11/11 [==============================] - 0s 1ms/step - loss: 0.2753 - accuracy: 0.8905
Epoch 384/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2931 - accuracy: 0.8686
Epoch 385/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2978 - accuracy: 0.8725
Epoch 386/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2835 - accuracy: 0.8808
Epoch 387/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2920 - accuracy: 0.8727
Epoch 388/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2640 - accuracy: 0.8942
Epoch 389/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2931 - accuracy: 0.8742
Epoch 390/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2742 - accuracy: 0.8846
Epoch 391/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2782 - accuracy: 0.8830
Epoch 392/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2835 - accuracy: 0.8740
Epoch 393/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2838 - accuracy: 0.8848
Epoch 394/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2885 - accuracy: 0.8832
Epoch 395/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2666 - accuracy: 0.8881
Epoch 396/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2766 - accuracy: 0.8806
Epoch 397/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2899 - accuracy: 0.8744
Epoch 398/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2611 - accuracy: 0.8933
Epoch 399/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2929 - accuracy: 0.8748
Epoch 400/400
11/11 [==============================] - 0s 2ms/step - loss: 0.2997 - accuracy: 0.8683
```

In [399…

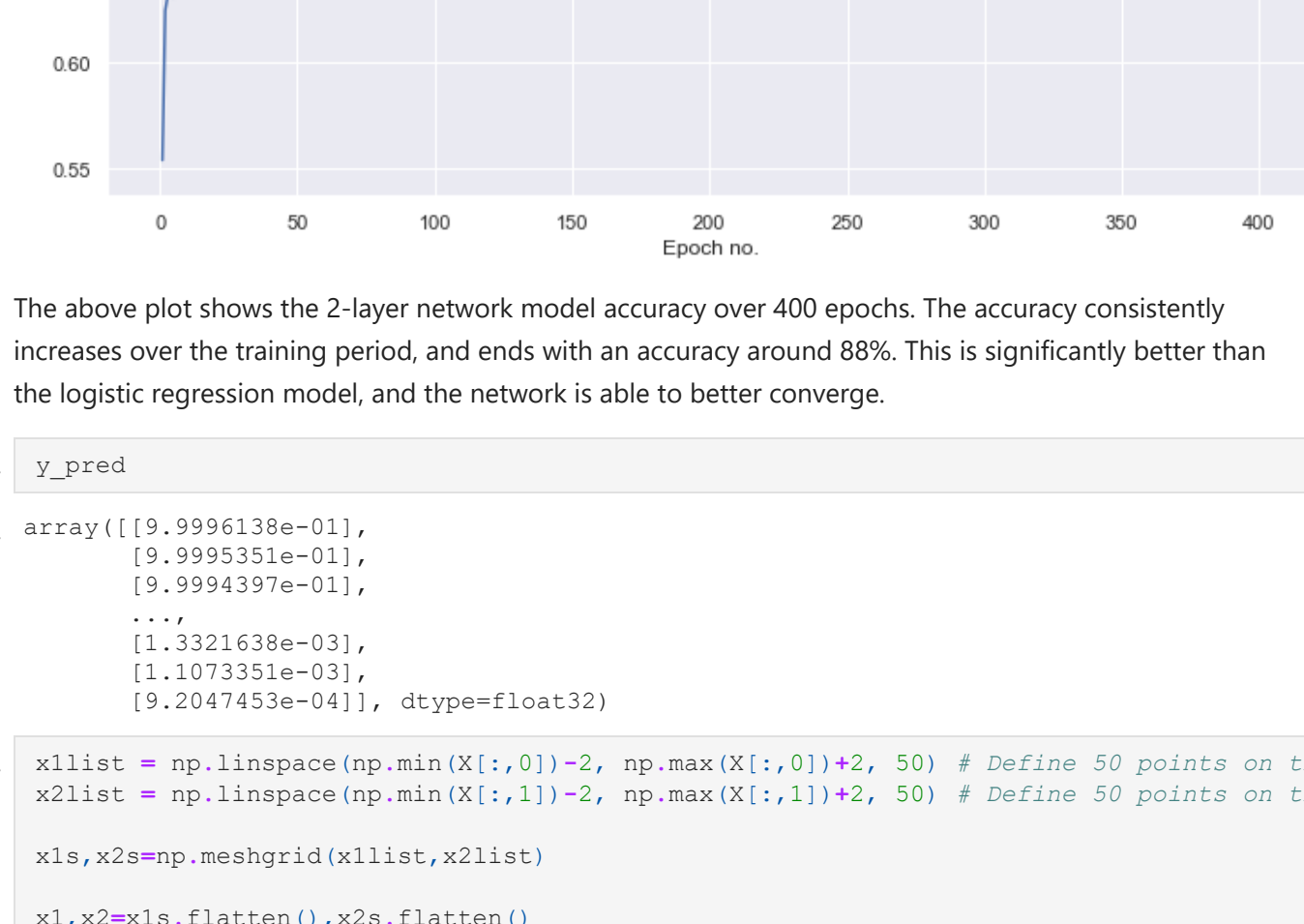
```
p = sns.lineplot(data=historyDF,y='loss',x='epoch')
_=p.set(title="Binary Cross Entropy Loss for 2-layer network over 400 epochs",ylabel=
```



The above plot shows the 2-layer network model loss over 400 epochs. The model continues to converge, after where the logistic model stops, and has lower overall loss than the logistic functions.

In [400…

```
historyDF = pd.DataFrame(history.history)
historyDF['epoch']=historyDF.index+1
p = sns.lineplot(data=historyDF,y='accuracy',x='epoch')
_=p.set(title="Model Accuracy for 2-layer network over 400 epochs",ylabel="BCE Loss",
```



The above plot shows the 2-layer network model accuracy over 400 epochs. The accuracy consistently increases over the training period, and ends with an accuracy around 88%. This is significantly better than the logistic regression model, and the network is able to better converge.

In [401…

```
y_pred
```

Out[401…

```
array([[9.9996138e-01],
       [9.9995351e-01],
       [9.9994397e-01],
       ...,
       [1.3321638e-03],
       [1.1073351e-03],
       [9.2047453e-04]], dtype=float32)
```

In [402…

```
x1list = np.linspace(np.min(X[:,0])-2, np.max(X[:,0])+2, 50) # Define 50 points on the
x2list = np.linspace(np.min(X[:,1])-2, np.max(X[:,1])+2, 50) # Define 50 points on the

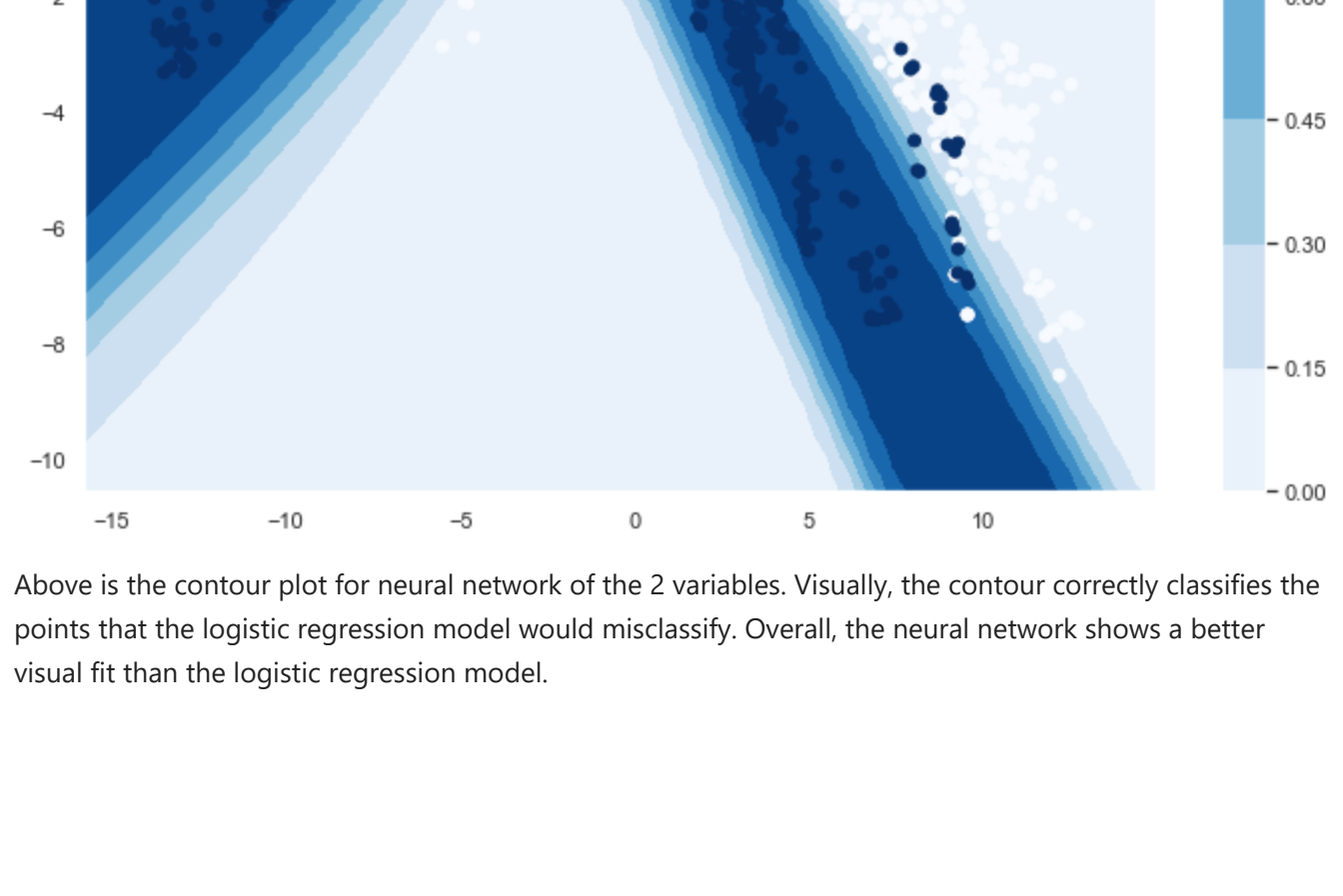
x1s,x2s=np.meshgrid(x1list,x2list)

x1,x2=x1s.flatten(),x2s.flatten()
grid = np.vstack((x1,x2)).T
y_pred = model.predict(grid)
y_preds = y_pred[:,1].reshape(x1s.shape)

from matplotlib.colors import Colormap
plt.figure()
plt.contourf(x1s,x2s,y_preds,cmap='Blues')
plt.colorbar()
plt.scatter(X[:,0],X[:,1],c=Y,cmap='Blues')
```

Out[402…

```
<matplotlib.collections.PathCollection at 0x26ba7a8beb0>
```



Above is the contour plot for neural network of the 2 variables. Visually, the contour correctly classifies the points that the logistic regression model would misclassify. Overall, the neural network shows a better visual fit than the logistic regression model.