

# M22AI564\_ANN\_2

April 29, 2023

## Mounting the Goodle Drive to Get the Dataset

```
[ ]: from google.colab import drive
drive.mount('/content/drive')
```

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force\_remount=True).

## #Data Preprocessing

## Converting the Train Image Data set into Numpy Array

```
[ ]: import os
import cv2
import numpy as np
from google.colab import drive
from matplotlib import pyplot as plt

# Mount your Google Drive
drive.mount('/content/drive')

# Define the path to the train and test data directories
train_path = "/content/drive/MyDrive/Dataset/train"

# Get the list of all folders in the train directory
folders = os.listdir(train_path)

# Define the image size and the number of channels
img_size = 28
num_channels = 1

# Define the empty lists to store the images and their respective labels
x_train = []
y_train = []

# Loop through each folder and read the images
for folder in folders:
    # Define the path to the current folder
```

```

folder_path = os.path.join(train_path, folder)
# Get the list of all image files in the current folder
files = os.listdir(folder_path)
# Loop through each image and read it
for file in files:
    # Define the path to the current image
    img_path = os.path.join(folder_path, file)
    # Read the image and resize it to the defined size
    img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
    img = cv2.resize(img, (img_size, img_size))
    x_train.append(img.flatten() / 255)
    # Append the image and its respective label to the lists
    #x_train.append(img)
    y_train.append(int(folder))

# Convert the lists to numpy arrays
x_train = np.array(x_train)
y_train = np.array(y_train)

# Print the shape of the training data and target labels
print("Training data shape:", x_train.shape)
print("Training labels shape:", y_train.shape)

```

Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive", force\_remount=True).

Training data shape: (1000, 784)

Training labels shape: (1000,)

### Converting the Test Image Data set into Numpy Array

```

[ ]: # Define the path to the train and test data directories
test_path = "/content/drive/MyDrive/Dataset/val"

# Get the list of all folders in the train directory
folders = os.listdir(test_path)

# Define the image size and the number of channels
img_size = 28
num_channels = 1

# Define the empty lists to store the images and their respective labels
x_test = []
y_test = []

# Loop through each folder and read the images
for folder in folders:
    # Define the path to the current folder
    folder_path = os.path.join(test_path, folder)

```

```

# Get the list of all image files in the current folder
files = os.listdir(folder_path)
# Loop through each image and read it
for file in files:
    # Define the path to the current image
    img_path = os.path.join(folder_path, file)
    # Read the image and resize it to the defined size
    img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
    img = cv2.resize(img, (img_size, img_size))
    x_test.append(img.flatten() / 255)
    # Append the image and its respective label to the lists
    #x_train.append(img)
    y_test.append(int(folder))

# Convert the lists to numpy arrays
x_test = np.array(x_test)
y_test = np.array(y_test)

# Print the shape of the training data and target labels
print("Training data shape:", x_test.shape)
print("Training labels shape:", y_test.shape)

```

Training data shape: (178, 784)

Training labels shape: (178,)

Creating the CSV File named as Output and storing the train data numpy inside it with the corresponding labels and pixels

```

[ ]: import numpy as np
# create a list of column names
# create a list of column names for the Xtrain data
column_names = ["pixel" + str(i) for i in range(784)]

# stack the Ytrain and Xtrain arrays horizontally
combined_data = np.column_stack((y_train, x_train))

# save the combined data to a CSV file
np.savetxt("output.csv", combined_data, delimiter=",", header="label," + ",".
    join(column_names), comments="")

```

Creating the CSV File named as testoutput and storing the test data numpy inside it with the corresponding labels and pixels

```

[ ]: import numpy as np
# create a list of column names for the Xtrain data
column_names = ["pixel" + str(i) for i in range(784)]

# stack the Ytrain and Xtrain arrays horizontally

```

```
combined_data = np.column_stack((y_test, x_test))

# save the combined data to a CSV file
np.savetxt("testoutput.csv", combined_data, delimiter=",", header="label," +
    "\n", ".join(column_names), comments="")
```

## Data visualization-Train Data CSV File

```
[ ]: import pandas as pd

data = pd.read_csv('output.csv')
data['label'] = data['label'].astype(int)
data.head(200)
```

```
[ ]:      label  pixel0  pixel1  pixel2  pixel3  pixel4  pixel5  pixel6  \
0         6      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
1         6      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
2         6      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
3         6      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
4         6      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
..      ...      ...      ...      ...      ...      ...      ...
195        2      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
196        2      1.0      1.0  1.000000  0.964706  0.929412  0.929412  0.066667
197        2      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000
198        2      1.0      1.0  0.972549  0.929412  0.929412  0.929412  0.929412
199        2      1.0      1.0  1.000000  1.000000  1.000000  1.000000  1.000000

      pixel7  pixel8  ...  pixel774  pixel775  pixel776  pixel777  \
0  1.000000  1.000000  ...  0.929412  0.929412  0.929412  0.929412
1  1.000000  1.000000  ...  0.000000  0.000000  0.000000  0.000000
2  1.000000  1.000000  ...  0.000000  0.000000  0.000000  0.000000
3  1.000000  1.000000  ...  0.929412  0.929412  0.929412  0.933333
4  1.000000  1.000000  ...  0.929412  0.984314  1.000000  1.000000
..      ...      ...  ...      ...      ...      ...      ...
195  1.000000  0.984314  ...  1.000000  1.000000  1.000000  1.000000
196  0.000000  0.000000  ...  1.000000  1.000000  1.000000  1.000000
197  1.000000  1.000000  ...  1.000000  1.000000  1.000000  1.000000
198  0.000000  0.000000  ...  1.000000  1.000000  1.000000  1.000000
199  0.996078  0.929412  ...  1.000000  1.000000  1.000000  1.000000

      pixel778  pixel779  pixel780  pixel781  pixel782  pixel783
0  0.945098  1.000000  1.000000  1.000000  1.000000  1.000000
1  0.200000  0.929412  0.929412  0.929412  0.929412  0.929412
2  0.000000  0.000000  0.000000  0.000000  0.729412  0.929412
3  1.000000  1.000000  1.000000  1.000000  1.000000  1.000000
4  1.000000  1.000000  1.000000  1.000000  1.000000  1.000000
..      ...      ...      ...      ...      ...      ...
```

```

195  1.000000  0.972549  0.929412  0.333333  0.000000  0.066667
196  1.000000  1.000000  0.964706  0.333333  0.000000  0.000000
197  1.000000  0.972549  0.462745  0.000000  0.000000  0.000000
198  1.000000  1.000000  1.000000  0.952941  0.200000  0.000000
199  0.984314  0.929412  0.462745  0.000000  0.729412  0.996078

```

[200 rows x 785 columns]

## Data visualization-Test Data CSV File

```
[ ]: import pandas as pd
```

```

testdata = pd.read_csv('testoutput.csv')
testdata['label'] = testdata['label'].astype(int)
testdata.head(178)

```

```

[ ]:      label  pixel0  pixel1  pixel2  pixel3  pixel4  pixel5  pixel6  \
0         4      1.0      1.0  1.000000  1.000000      1.0  1.000000  0.933333
1         4      1.0      1.0  1.000000  1.000000      1.0  1.000000  1.000000
2         4      1.0      1.0  0.972549  0.462745      0.0  0.000000  0.862745
3         4      1.0      1.0  1.000000  1.000000      1.0  1.000000  0.933333
4         4      1.0      1.0  1.000000  1.000000      1.0  0.945098  0.066667
..      ...      ...      ...      ...      ...      ...      ...
173        7      1.0      1.0  1.000000  1.000000      1.0  1.000000  1.000000
174        7      1.0      1.0  1.000000  1.000000      1.0  0.945098  0.929412
175        7      1.0      1.0  1.000000  1.000000      1.0  1.000000  1.000000
176        7      1.0      1.0  1.000000  1.000000      1.0  1.000000  1.000000
177        7      1.0      1.0  1.000000  1.000000      1.0  1.000000  1.000000

```

```

      pixel7  pixel8  ...  pixel774  pixel775  pixel776  pixel777  \
0  0.862745  0.000000  ...  0.596078  0.929412  0.996078      1.0
1  1.000000  1.000000  ...  1.000000  1.000000  1.000000      1.0
2  1.000000  1.000000  ...  1.000000  1.000000  1.000000      1.0
3  0.929412  0.729412  ...  0.000000  0.729412  0.996078      1.0
4  0.000000  0.200000  ...  1.000000  1.000000  1.000000      1.0
..      ...      ...  ...      ...      ...      ...
173  1.000000  1.000000  ...  1.000000  1.000000  1.000000      1.0
174  0.929412  0.929412  ...  1.000000  1.000000  1.000000      1.0
175  1.000000  1.000000  ...  1.000000  1.000000  1.000000      1.0
176  0.996078  0.929412  ...  1.000000  1.000000  1.000000      1.0
177  0.996078  0.929412  ...  1.000000  1.000000  1.000000      1.0

```

```

      pixel778  pixel779  pixel780  pixel781  pixel782  pixel783
0           1.0           1.0           1.0           1.0           1.0           1.0
1           1.0           1.0           1.0           1.0           1.0           1.0
2           1.0           1.0           1.0           1.0           1.0           1.0
3           1.0           1.0           1.0           1.0           1.0           1.0

```

4	1.0	1.0	1.0	1.0	1.0	1.0
..	...	...	...	...	...	...
173	1.0	1.0	1.0	1.0	1.0	1.0
174	1.0	1.0	1.0	1.0	1.0	1.0
175	1.0	1.0	1.0	1.0	1.0	1.0
176	1.0	1.0	1.0	1.0	1.0	1.0
177	1.0	1.0	1.0	1.0	1.0	1.0

[178 rows x 785 columns]

## Data visualization-Printing Random Image in Train Data

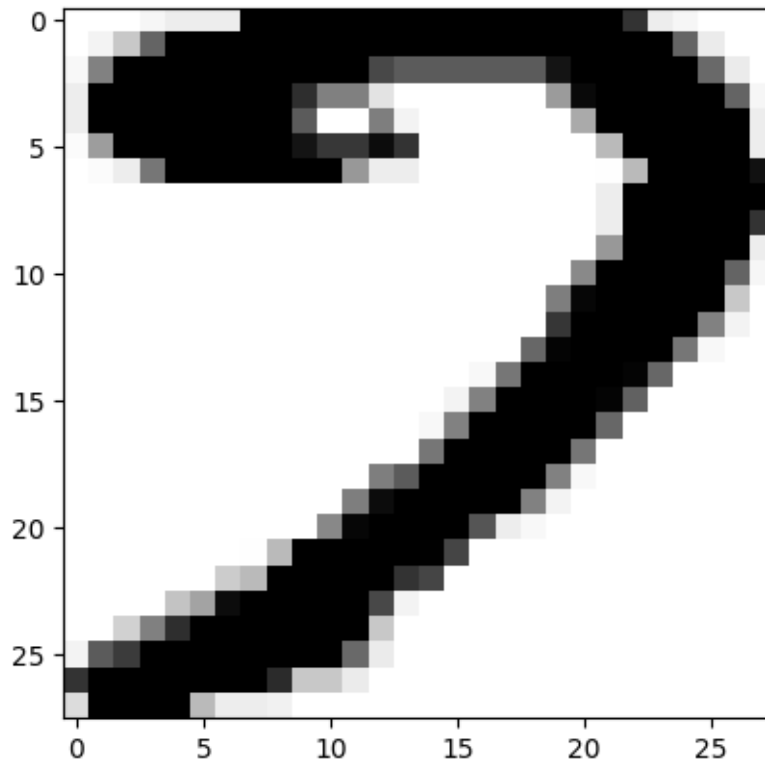
```
[ ]: data = np.array(data)
m, n = data.shape
np.random.shuffle(data) # shuffle before splitting into dev and training sets

# data_dev = data[0:100].T
# Y_dev = data_dev[0].astype(int)
# X_dev = data_dev[1:n]

data_train = data[0:m].T
Y_train = data_train[0].astype(int)
X_train = data_train[1:n]
_,m_train = X_train.shape

label = Y_train[1]
print(label)
current_image = X_train[:, 1, None]
current_image = current_image.reshape((28, 28)) * 255
plt.gray()
plt.imshow(current_image, interpolation='nearest')
plt.show()
```

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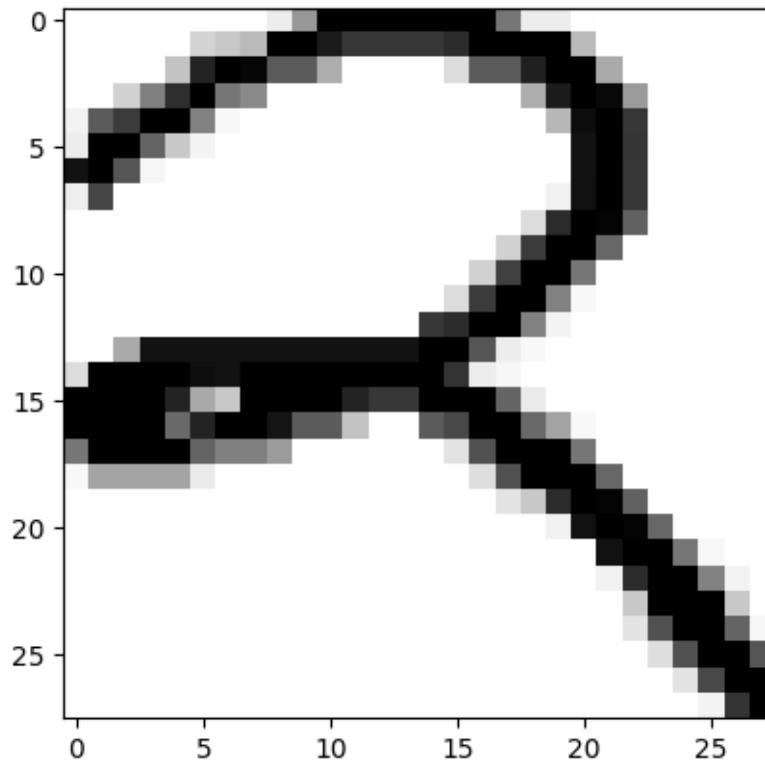


### Data visualization-Printing Random Image in Test Data

```
[ ]: testdata = np.array(testdata)
m, n = testdata.shape
np.random.shuffle(testdata) # shuffle before splitting into dev and training
    ↳ sets

data_dev = testdata[0:m].T
Y_dev = data_dev[0].astype(int)
X_dev = data_dev[1:n]

label = Y_dev[1]
print(label)
current_image = X_dev[:, 1, None]
current_image = current_image.reshape((28, 28)) * 255
plt.gray()
plt.imshow(current_image, interpolation='nearest')
plt.show()
```



### Checking Size and shape of Train Data

```
[ ]: print(Y_train.shape)
      print(X_train.shape)
```

```
(1000,)
(784, 1000)
```

### Checking Size and shape of Test Data

```
[ ]: print(Y_dev.shape)
      print(X_dev.shape)
```

```
(178,)
(784, 178)
```

### #NEURAL NETWORK FROM SCRATCH

### Implementing NEURAL NETWORK FROM SCRATCH

```
[ ]: def init_params():
      W1 = np.random.rand(10, 784) - 0.5
      b1 = np.random.rand(10, 1) - 0.5
      W2 = np.random.rand(10, 10) - 0.5
```



```

    b2 = np.random.rand(10, 1) - 0.5
    return W1, b1, W2, b2

def ReLU(Z):
    return np.maximum(Z, 0)

def softmax(Z):
    A = np.exp(Z) / sum(np.exp(Z))
    return A

def forward_prop(W1, b1, W2, b2, X):
    Z1 = W1.dot(X) + b1
    A1 = ReLU(Z1)
    Z2 = W2.dot(A1) + b2
    A2 = softmax(Z2)
    return Z1, A1, Z2, A2

def ReLU_deriv(Z):
    return Z > 0

def one_hot(Y):
    one_hot_Y = np.zeros((Y.size, Y.max() + 1))
    one_hot_Y[np.arange(Y.size), Y] = 1
    one_hot_Y = one_hot_Y.T
    return one_hot_Y

def backward_prop(Z1, A1, Z2, A2, W1, W2, X, Y):
    one_hot_Y = one_hot(Y)
    dZ2 = A2 - one_hot_Y
    dW2 = 1 / m * dZ2.dot(A1.T)
    db2 = 1 / m * np.sum(dZ2)
    dZ1 = W2.T.dot(dZ2) * ReLU_deriv(Z1)
    dW1 = 1 / m * dZ1.dot(X.T)
    db1 = 1 / m * np.sum(dZ1)
    return dW1, db1, dW2, db2

def update_params(W1, b1, W2, b2, dW1, db1, dW2, db2, alpha):
    W1 = W1 - alpha * dW1
    b1 = b1 - alpha * db1
    W2 = W2 - alpha * dW2
    b2 = b2 - alpha * db2
    return W1, b1, W2, b2

```

```

[ ]: def get_predictions(A2):
    print("#"*100)
    print(A2)
    print(np.argmax(A2, 0))
    return np.argmax(A2, 0)

```

```

def get_accuracy(predictions, Y):
    print(predictions, Y)
    return np.sum(predictions == Y) / Y.size

def gradient_descent(X, Y, alpha, iterations):
    W1, b1, W2, b2 = init_params()
    for i in range(iterations):
        Z1, A1, Z2, A2 = forward_prop(W1, b1, W2, b2, X)
        dW1, db1, dW2, db2 = backward_prop(Z1, A1, Z2, A2, W1, W2, X, Y)
        W1, b1, W2, b2 = update_params(W1, b1, W2, b2, dW1, db1, dW2, db2,
    ↪alpha)
        if i % 10 == 0:
            print("Iteration: ", i)
            predictions = get_predictions(A2)
            print(get_accuracy(predictions, Y))
    return W1, b1, W2, b2

```

## Initializing the Parameters for the Model

```
[ ]: W1, b1, W2, b2 = gradient_descent(X_train, Y_train, 0.01, 4000)
```

Streaming output truncated to the last 5000 lines.

```

3 2 6 9 4 9 0 2 7 4 2 3 1 6 8 0 1 3 9 2 0 4 1 7 8 7 6 5 1 6 1 7 0 6 9 7 3
0 6 7 2 8 4 1 0 8 8 5 1 8 7 9 0 0 5 1 2 6 0 2 2 5 3 1 2 1 2 3 8 5 6 1 5 4
0 3 8 9 6 5 3 1 7 5 8 8 7 4 6 5 8 3 8 1 3 4 2 3 1 1 3 3 2 6 9 5 9 8 0 1 4
3 7 9 7 9 2 2 0 2 4 0 7 6 4 8 5 7 3 5 6 6 7 5 9 3 8 9 7 5 2 7 2 0 6 0 4 6
2 8 9 1 1 2 2 8 7 1 6 9 1 4 4 1 1 7 3 1 1 4 7 7 9 1 5 1 7 3 4 1 0 4 9 8 6
0 5 8 3 7 3 9 7 2 1 4 9 6 9 1 8 6 0 4 9 2 1 1 7 3 4 9 2 4 9 3 0 0 6 3 0 6
7 0 9 3 2 5 7 5 8 4 3 7 9 1 6 0 1 3 7 9 9 1 5 4 8 4 8 8 0 7 1 8 8 6 9 7 0
4 3 1 8 2 4 4 6 7 4 7 2 2 1 9 9 3 4 4 4 0 0 8 8 9 5 7 6 9 4 4 6 5 3 9 2 1
6 4 2 2 9 0 2 2 3 4 3 2 4 8 6 0 7 7 9 8 6 2 2 7 4 6 2 5 1 9 7 2 6 7 9 6 1
8 3 2 4 3 6 4 2 1 5 1 8 2 3 1 3 5 2 5 4 5 3 4 7 0 2 1 8 7 3 1 8 3 0 9 0 3
0 9 3 3 5 7 2 6 3 9 0 7 7 3 5 4 8 6 8 8 8 3 6 6 8 3 1 7 0 7 1 7 7 8 0 5 9
3 5 1 2 2 6 8 4 8 1 8 4 3 3 3 8 9 3 0 5 5 6 6 3 7 4 5 1 5 7 9 7 0 5 0 5 5
7 5 1 5 7 1 5 9 1 8 7 2 4 3 9 2 1 2 6 4 0 0 6 5 5 5 9 4 0 3 6 0 6 8 9 0 0
9 5 4 3 5 3 6 5 7 8 8 8 8 7 7 8 0 6 4 1 6 2 4 5 9 8 2 4 4 6 1 8 5 0 3 8 9
1 1 1 8 3 4 7 2 2 7 6 0 2 1 7 5 5 0 5 6 6 8 5 1 5 9 4 3 6 6 9 6 4 5 2 0 3
8 9 2 6 6 0 1 4 8 8 4 2 6 9 7 6 4 5 6 4 5 9 8 3 6 1 6 4 0 4 6 8 1 6 7 9 7
5 1 5 3 2 2 3 7 1 7 6 1 1 2 4 6 2 8 6 3 2 2 3 3 2 2 7 9 9 5 8 2 6 9 4 3 8
5 5 1 0 8 7 5 2 0 4 0 8 6 1 4 9 9 4 7 7 8 0 8 0 1 5 4 0 1 0 7 9 0 5 7 5 3
4 6 9 2 8 1 5 8 0 1 5 7 0 4 2 3 0 7 1 6 6 8 0 5 8 9 8 1 5 0 7 2 0 7 0 7 4
6 4 0 2 5 6 1 8 9 1 5 0 8 9 7 4 3 2 2 2 3 5 7 2 9 2 6 9 4 8 5 9 7 9 4 3 6
5 6 7 5 0 1 6 6 0 5 0 3 7 9 3 7 2 6 0 0 4 7 8 9 1 2 8 5 7 9 9 1 6 0 5 0 9
2] [0 7 5 3 8 9 8 0 3 0 2 4 0 9 4 0 9 9 2 4 5 9 9 9 2 1 5 1 6 7 8 3 1 3 1 3 2
6 6 2 7 0 1 8 3 3 2 5 0 2 2 3 8 3 3 9 4 7 9 9 3 4 4 0 1 2 9 5 3 8 5 7 8 3
3 2 3 5 9 8 0 8 2 1 1 8 2 3 0 6 6 9 7 0 8 4 4 4 2 7 0 0 5 0 7 2 2 9 2 9 2
5 2 0 8 8 6 1 8 3 3 6 9 1 3 0 4 6 9 5 6 8 4 2 4 4 4 5 0 2 8 9 8 6 5 1 5 3

```

0 5 6 9 3 9 0 4 8 7 7 9 1 7 6 9 6 1 1 5 7 7 9 5 3 0 1 4 4 8 6 5 6 1 6 1 3  
3 4 8 7 4 3 0 4 5 0 9 0 1 6 0 9 6 4 2 4 2 4 5 5 7 8 6 7 5 4 7 9 3 2 5 4 1  
3 2 6 9 4 9 0 2 7 4 2 3 1 6 8 0 1 3 9 2 0 4 1 7 8 7 6 5 1 6 1 7 0 6 9 7 3  
0 6 7 2 8 4 1 0 8 8 5 1 8 7 9 0 0 5 1 2 6 0 2 2 5 3 1 2 1 2 3 8 5 6 1 5 4  
0 3 8 9 6 5 3 1 7 5 8 8 7 4 6 5 8 3 8 1 3 4 2 3 1 1 3 3 2 6 9 5 9 8 0 1 4  
3 7 9 7 9 2 2 0 2 4 0 7 6 4 8 5 7 3 5 6 6 7 5 9 3 8 9 7 5 2 7 2 0 6 0 4 6  
2 8 9 1 1 2 2 8 7 1 6 9 1 4 4 1 1 7 3 1 1 4 7 7 9 1 5 1 7 3 4 1 0 4 9 8 6  
0 5 8 3 7 3 9 7 2 1 4 9 6 9 1 8 6 0 4 9 2 1 1 7 3 4 9 2 4 9 3 0 0 6 3 0 6  
7 0 9 3 2 5 7 5 8 4 3 7 9 1 6 0 1 3 7 9 9 1 5 4 8 4 8 8 0 7 1 8 8 6 9 7 0  
4 3 1 8 2 4 4 6 7 4 7 2 2 1 9 9 3 4 4 4 0 0 8 8 9 5 7 6 9 4 4 6 5 3 9 2 1  
6 4 2 2 9 0 2 3 3 4 3 2 4 8 6 0 7 7 9 8 6 2 2 7 4 6 2 5 1 9 7 2 6 7 9 6 1  
8 3 2 4 3 6 4 2 1 5 1 8 2 3 1 3 5 2 5 4 5 3 4 7 0 2 1 8 7 3 1 8 3 0 9 0 3  
0 9 3 3 5 7 2 6 3 9 0 7 7 3 5 4 8 6 8 8 8 3 6 6 8 3 1 7 0 7 1 7 7 8 0 5 9  
3 5 1 2 2 6 8 4 8 1 8 4 3 3 3 8 9 3 0 5 5 6 6 3 7 4 5 1 5 7 9 7 0 5 0 5 5  
7 5 1 5 7 1 5 9 1 8 7 2 4 3 9 2 1 2 6 4 0 0 6 5 5 5 9 4 0 3 6 0 6 8 9 0 0  
9 5 4 3 5 3 6 5 7 8 8 8 8 7 7 8 0 6 4 1 6 2 4 5 9 8 2 4 4 6 1 8 5 0 3 8 9  
1 1 1 8 3 4 7 2 2 7 6 0 2 1 7 5 5 0 5 6 6 8 5 1 5 9 4 3 6 6 9 6 4 5 2 0 3  
8 9 2 6 6 0 1 4 8 8 4 2 6 9 7 6 4 5 6 4 5 9 8 3 6 1 6 4 0 4 6 8 1 6 7 9 7  
5 1 5 3 2 2 3 7 1 7 6 1 1 2 4 6 2 8 6 3 2 2 3 3 2 2 7 9 9 5 8 2 6 9 4 3 8  
5 5 1 0 8 7 5 2 0 4 0 8 6 1 4 9 9 4 7 7 8 0 8 0 1 5 4 0 1 0 7 9 0 5 7 5 3  
4 6 9 2 8 1 5 8 0 1 5 7 0 4 2 3 0 7 1 6 6 8 0 5 8 9 8 1 5 0 7 2 0 7 0 7 4  
6 4 0 2 5 6 1 8 9 1 5 0 8 9 7 4 3 2 2 2 3 5 7 2 9 2 6 9 4 8 5 9 7 9 4 3 6  
5 6 7 5 0 1 6 6 0 5 0 3 7 9 3 7 2 6 0 0 4 7 8 9 1 2 8 5 7 9 9 1 6 0 5 0 9

2]

0.999

Iteration: 3500

#####  
#####

[9.99989601e-01 6.38735290e-07 2.84648178e-17 ... 9.99343708e-01  
1.05761629e-10 1.65787474e-13]  
[1.03983555e-05 8.53630264e-04 6.25707836e-14 ... 6.55607549e-04  
1.17153582e-07 1.30167600e-05]  
[1.22487959e-10 7.12414658e-09 6.27817301e-09 ... 8.63924545e-08  
8.90383908e-22 9.72400061e-01]

...

[2.20347150e-10 9.98845256e-01 6.69887163e-09 ... 4.80647490e-07  
3.17745368e-14 1.63111973e-16]  
[1.24101274e-15 9.66752635e-17 7.81877316e-10 ... 1.13711690e-10  
4.87642278e-06 1.18440160e-14]  
[1.40229730e-14 2.35006503e-07 3.36839385e-14 ... 1.14943244e-07  
9.99994814e-01 8.99864379e-11]]

[0 7 5 3 8 9 8 0 3 0 2 4 0 9 4 0 9 9 2 4 5 9 9 9 2 1 5 1 6 7 8 3 1 3 1 3 2  
6 6 2 7 0 1 8 3 3 2 5 0 2 2 3 8 3 3 9 4 7 9 9 3 4 4 0 1 2 9 5 3 8 5 7 8 3  
3 2 3 5 9 8 0 8 2 1 1 8 2 3 0 6 6 9 7 0 8 4 4 4 2 7 0 0 5 0 7 2 2 9 2 9 2  
5 2 0 8 8 6 1 8 3 3 6 9 1 3 0 4 6 9 5 6 8 4 2 4 4 4 5 0 2 8 9 8 6 5 1 5 3  
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3 7 9 7 9 2 2 0 2 4 0 7 6 4 8 5 7 3 5 6 6 7 5 9 3 8 9 7 5 2 7 2 0 6 0 4 6
2 8 9 1 1 2 2 8 7 1 6 9 1 4 4 1 1 7 3 1 1 4 7 7 9 1 5 1 7 3 4 1 0 4 9 8 6
0 5 8 3 7 3 9 7 2 1 4 9 6 9 1 8 6 0 4 9 2 1 1 7 3 4 9 2 4 9 3 0 0 6 3 0 6
7 0 9 3 2 5 7 5 8 4 3 7 9 1 6 0 1 3 7 9 9 1 5 4 8 4 8 8 0 7 1 8 8 6 9 7 0
4 3 1 8 2 4 4 6 7 4 7 2 2 1 9 9 3 4 4 4 0 0 8 8 9 5 7 6 9 4 4 6 5 3 9 2 1
6 4 2 2 9 0 2 3 3 4 3 2 4 8 6 0 7 7 9 8 6 2 2 7 4 6 2 5 1 9 7 2 6 7 9 6 1
8 3 2 4 3 6 4 2 1 5 1 8 2 3 1 3 5 2 5 4 5 3 4 7 0 2 1 8 7 3 1 8 3 0 9 0 3
0 9 3 3 5 7 2 6 3 9 0 7 7 3 5 4 8 6 8 8 8 3 6 6 8 3 1 7 0 7 1 7 7 8 0 5 9
3 5 1 2 2 6 8 4 8 1 8 4 3 3 3 8 9 3 0 5 5 6 6 3 7 4 5 1 5 7 9 7 0 5 0 5 5
7 5 1 5 7 1 5 9 1 8 7 2 4 3 9 2 1 2 6 4 0 0 6 5 5 5 9 4 0 3 6 0 6 8 9 0 0
9 5 4 3 5 3 6 5 7 8 8 8 8 7 7 8 0 6 4 1 6 2 4 5 9 8 2 4 4 6 1 8 5 0 3 8 9
1 1 1 8 3 4 7 2 2 7 6 0 2 1 7 5 5 0 5 6 6 8 5 1 5 9 4 3 6 6 9 6 4 5 2 0 3
8 9 2 6 6 0 1 4 8 8 4 2 6 9 7 6 4 5 6 4 5 9 8 3 6 1 6 4 0 4 6 8 1 6 7 9 7
5 1 5 3 2 2 3 7 1 7 6 1 1 2 4 6 2 8 6 3 2 2 3 3 2 2 7 9 9 5 8 2 6 9 4 3 8
5 5 1 0 8 7 5 2 0 4 0 8 6 1 4 9 9 4 7 7 8 0 8 0 1 5 4 0 1 0 7 9 0 5 7 5 3
4 6 9 2 8 1 5 8 0 1 5 7 0 4 2 3 0 7 1 6 6 8 0 5 8 9 8 1 5 0 7 2 0 7 0 7 4
6 4 0 2 5 6 1 8 9 1 5 0 8 9 7 4 3 2 2 2 3 5 7 2 9 2 6 9 4 8 5 9 7 9 4 3 6
5 6 7 5 0 1 6 6 0 5 0 3 7 9 3 7 2 6 0 0 4 7 8 9 1 2 8 5 7 9 9 1 6 0 5 0 9
2]
0.999

```

### ##Validating the Model

```

[ ]: def make_predictions(X, W1, b1, W2, b2):
    _, _, _, A2 = forward_prop(W1, b1, W2, b2, X)
    predictions = get_predictions(A2)
    return predictions

def test_prediction(index, W1, b1, W2, b2):
    current_image = X_train[:, index, None]
    prediction = make_predictions(X_train[:, index, None], W1, b1, W2, b2)
    label = Y_train[index]
    print("Prediction: ", prediction)
    print("Label: ", label)

```

```

    current_image = current_image.reshape((28, 28)) * 255
    plt.gray()
    plt.imshow(current_image, interpolation='nearest')
    plt.show()

def test_prediction1(index, W1, b1, W2, b2):
    current_image = X_dev[:, index, None]
    prediction = make_predictions(X_dev[:, index, None], W1, b1, W2, b2)
    label = Y_dev[index]
    print("Prediction: ", prediction)
    print("Label: ", label)

    current_image = current_image.reshape((28, 28)) * 255
    plt.gray()
    plt.imshow(current_image, interpolation='nearest')
    plt.show()

```

### ##Checking the Predictions by the Model With Both Train and Test Data

```

[ ]: test_prediction(0, W1, b1, W2, b2)
test_prediction(1, W1, b1, W2, b2)
test_prediction(2, W1, b1, W2, b2)
test_prediction(3, W1, b1, W2, b2)

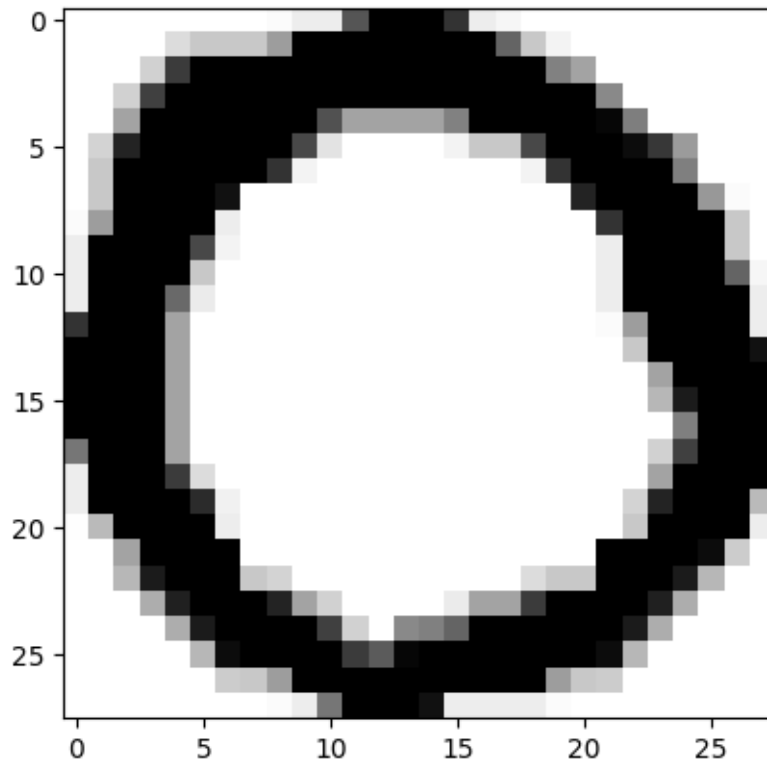
test_prediction1(0, W1, b1, W2, b2)
test_prediction1(1, W1, b1, W2, b2)
test_prediction1(2, W1, b1, W2, b2)
test_prediction1(3, W1, b1, W2, b2)

```

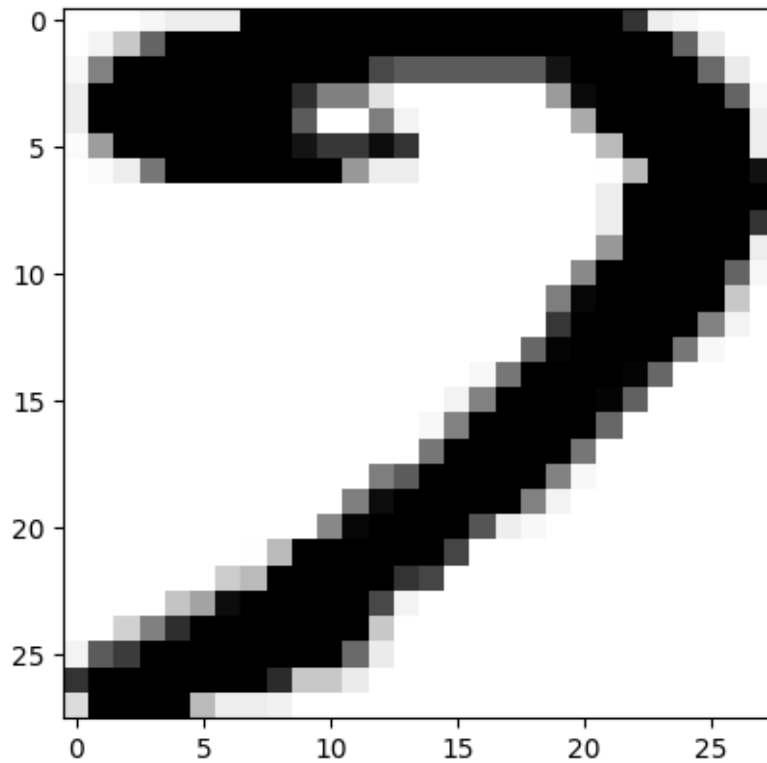
```

#####
#####
[[9.99991845e-01]
 [8.15432695e-06]
 [8.09988370e-11]
 [4.02682753e-30]
 [1.50116260e-21]
 [1.36173439e-14]
 [1.28114583e-19]
 [1.41424744e-10]
 [5.38863753e-16]
 [7.12272766e-15]]
[0]
Prediction:  [0]
Label:  0

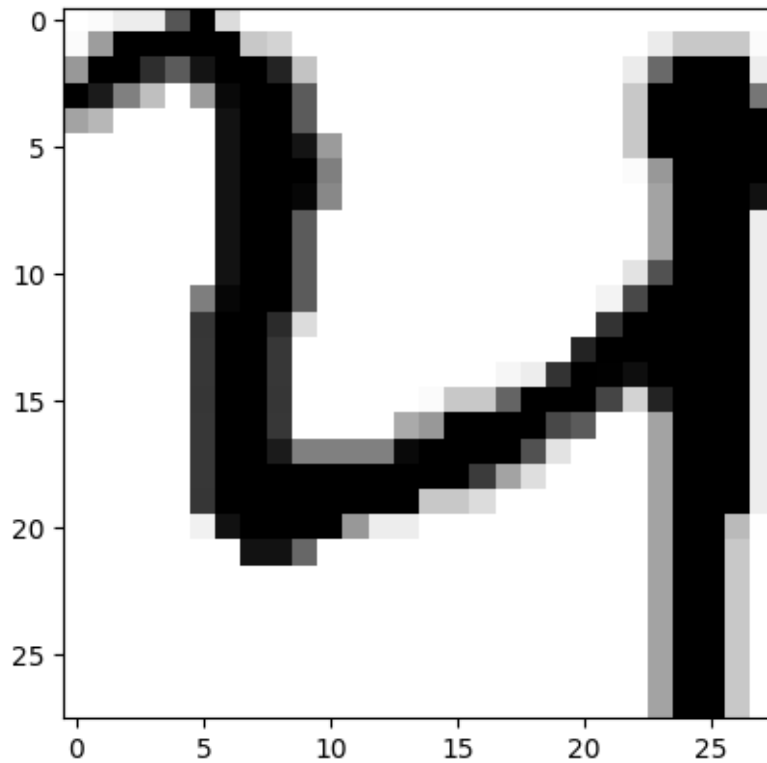
```



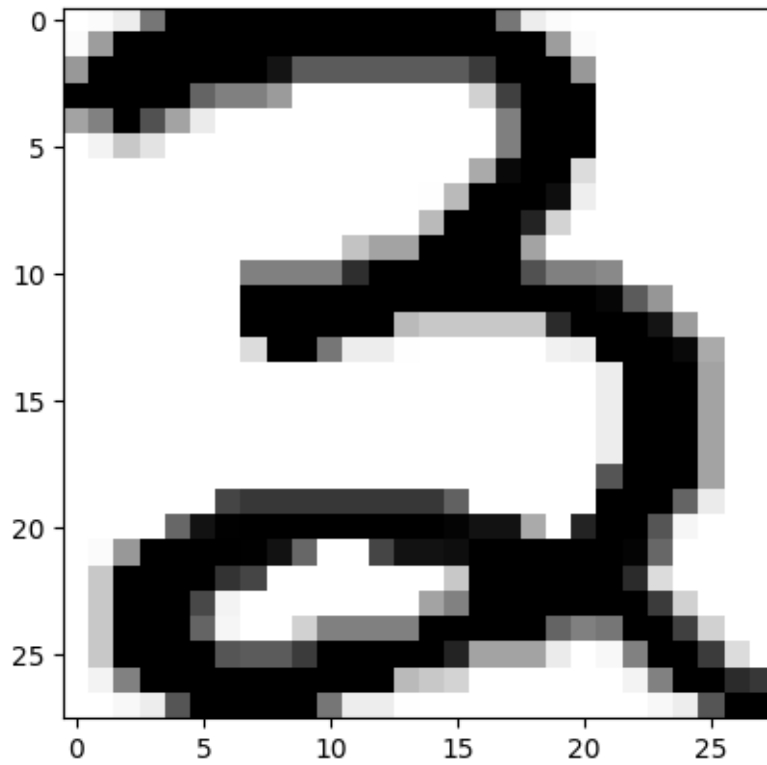
```
#####  
#####  
[[4.40332248e-07]  
 [6.97515118e-04]  
 [3.78932233e-09]  
 [3.60202303e-11]  
 [2.13659220e-04]  
 [2.53836232e-12]  
 [4.63989877e-15]  
 [9.99088219e-01]  
 [2.68975843e-17]  
 [1.62377705e-07]]  
[7]  
Prediction: [7]  
Label: 7
```



```
#####
#####
[[8.87100190e-18]
 [2.00545946e-14]
 [3.45130783e-09]
 [6.36167388e-14]
 [7.14438231e-07]
 [9.9999275e-01]
 [2.97868426e-09]
 [4.17082068e-09]
 [4.27798449e-10]
 [1.30573087e-14]]
[5]
Prediction:  [5]
Label:  5
```

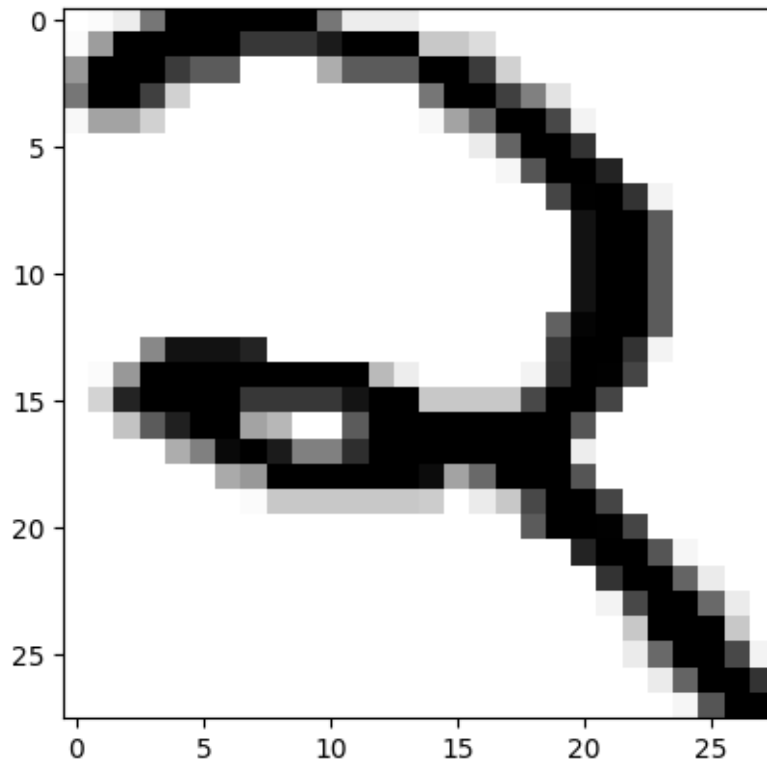


```
#####
#####
[[2.15918530e-11]
 [1.35341478e-04]
 [2.39004240e-07]
 [9.99852374e-01]
 [2.83217487e-07]
 [1.22463784e-12]
 [3.67368389e-06]
 [1.09383900e-12]
 [1.07653897e-07]
 [7.98089219e-06]]
[3]
Prediction:  [3]
Label:  3
```

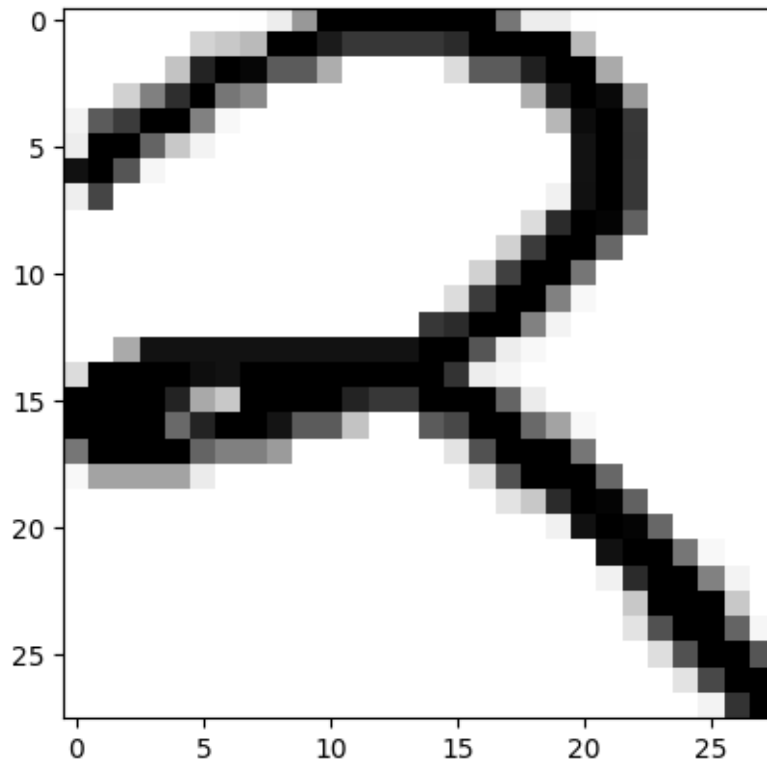


```
#####  
#####  
[[4.16696672e-14]  
 [6.26792105e-05]  
 [9.96133000e-01]  
 [1.17773973e-03]  
 [1.35302486e-07]  
 [2.62570218e-03]  
 [7.28556898e-07]  
 [2.84065691e-12]  
 [9.78391782e-09]  
 [5.63315199e-09]]  
[2]  
Prediction:  [2]  
Label:  2
```

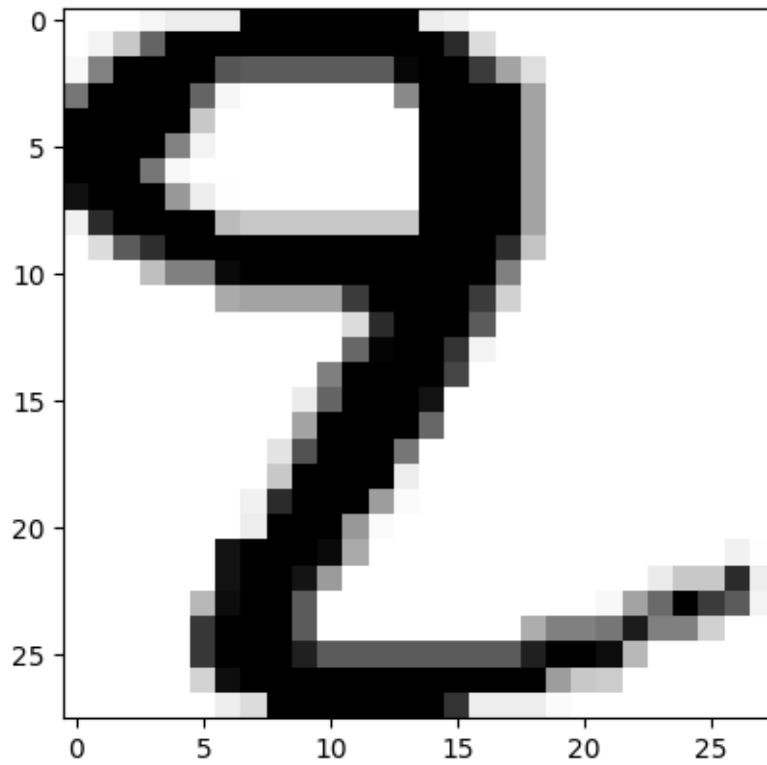




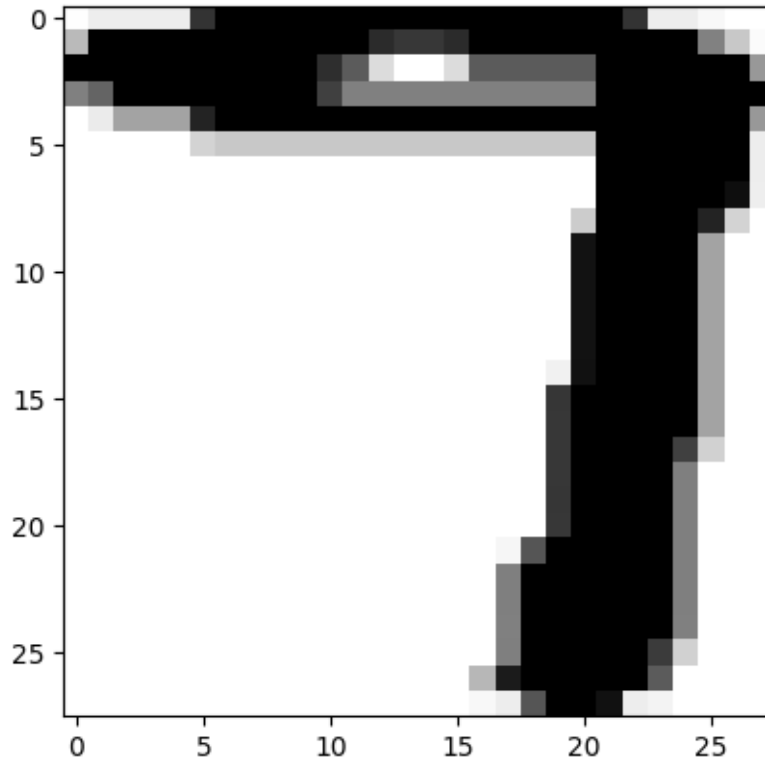
```
#####
#####
[[1.80837842e-13]
 [1.31990060e-04]
 [9.99657979e-01]
 [2.10028060e-04]
 [4.01200356e-12]
 [1.87198642e-09]
 [5.41658762e-10]
 [3.17700440e-13]
 [1.23190207e-14]
 [1.11241770e-10]]
[2]
Prediction:  [2]
Label:  2
```



```
#####  
#####  
[[2.67292175e-07]  
 [9.92806716e-01]  
 [2.07972362e-10]  
 [1.85246281e-07]  
 [3.23446528e-04]  
 [1.31173667e-10]  
 [4.37804442e-09]  
 [4.70040117e-10]  
 [1.72053496e-05]  
 [6.85217404e-03]]  
[1]  
Prediction:  [1]  
Label:  1
```



```
#####  
#####  
[[6.39741211e-07]  
 [9.99243925e-01]  
 [1.13578946e-04]  
 [1.03477333e-09]  
 [1.24957894e-07]  
 [1.31910864e-09]  
 [8.31816270e-12]  
 [6.41516709e-04]  
 [5.32566375e-16]  
 [2.12572922e-07]]  
[1]  
Prediction: [1]  
Label: 1
```



```
[ ]: dev_predictions = make_predictions(X_dev, W1, b1, W2, b2)
      get_accuracy(dev_predictions, Y_dev)
```

```
#####
#####
[[4.16696672e-14 1.80837842e-13 2.67292175e-07 ... 1.36800138e-08
  5.54959792e-09 8.03985953e-14]
 [6.26792105e-05 1.31990060e-04 9.92806716e-01 ... 1.64616787e-06
  9.99207935e-01 6.54667153e-11]
 [9.96133000e-01 9.99657979e-01 2.07972362e-10 ... 8.34260092e-13
  1.24098336e-05 1.30871302e-09]
 ...
 [2.84065691e-12 3.17700440e-13 4.70040117e-10 ... 1.19442321e-08
  8.09826572e-05 6.74908182e-11]
 [9.78391782e-09 1.23190207e-14 1.72053496e-05 ... 5.84675007e-03
  6.64936549e-15 1.03299375e-03]
 [5.63315199e-09 1.11241770e-10 6.85217404e-03 ... 6.43741570e-01
  3.21839156e-05 3.93302527e-08]]
[2 2 1 1 4 4 1 9 8 8 2 5 0 1 8 3 9 8 7 9 9 0 8 6 7 8 9 7 6 2 7 6 8 0 7 0 4
 8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
 4 5 4 0 1 7 6 9 1 2 5 8 6 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 7 1 9 0 3
 4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 4 2 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6]
```

```

6 4 7 4 2 3 1 9 0 7 8 0 6 5 3 3 6 8 8 8 7 8 7 9 2 4 9 9 1 5]
[2 2 1 1 4 4 1 9 8 8 2 5 0 1 8 3 9 8 7 9 9 0 8 6 7 8 9 7 6 2 7 6 8 0 7 0 4
8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
4 5 4 0 1 7 6 9 1 2 5 8 6 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 7 1 9 0 3
4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 4 2 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6
6 4 7 4 2 3 1 9 0 7 8 0 6 5 3 3 6 8 8 8 7 8 7 9 2 4 9 9 1 5] [2 2 1 1 4 4 1 2 8
8 2 0 0 1 8 3 9 8 1 8 9 0 8 6 7 8 9 1 6 2 7 6 8 0 7 0 4
8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
4 5 4 0 1 7 6 9 1 2 2 8 3 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 1 7 9 0 3
4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 2 3 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6
6 4 7 4 2 3 1 9 0 7 8 0 6 1 3 2 6 8 8 8 7 8 7 9 2 4 9 9 7 5]

```

```
[ ]: 0.9213483146067416
```

Also Checked the Model By Implementing using Keras

```

[ ]: import pandas as pd
import numpy as np
import tensorflow as tf
from sklearn.model_selection import train_test_split
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout
import matplotlib.pyplot as plt

# Load the data from CSV files
train_data = pd.read_csv("output.csv")
test_data = pd.read_csv("testoutput.csv")

# Split the data into input features (pixels) and target variable (labels)
X_train = train_data.iloc[:, 1:].values.astype('float32') / 255.0
y_train = train_data.iloc[:, 0].values.astype('int32')

X_test = test_data.iloc[:, 1:].values.astype('float32') / 255.0
y_test = test_data.iloc[:, 0].values.astype('int32')

# Split the training data into train and validation sets
X_train, X_val, y_train, y_val = train_test_split(X_train, y_train, test_size=0.
↪2, random_state=42)

# Define the model architecture
model = Sequential([
    Dense(512, activation='relu', input_shape=(784,)),
    Dropout(0.2),
    Dense(256, activation='relu'),
    Dropout(0.2),
    Dense(10, activation='softmax')
])

```

```

# Compile the model
model.compile(loss='sparse_categorical_crossentropy', optimizer='adam',
    ↪metrics=['accuracy'])

# Train the model
history = model.fit(X_train, y_train, epochs=200, batch_size=32,
    ↪validation_data=(X_val, y_val))

# Evaluate the model on the test set
test_loss, test_acc = model.evaluate(X_test, y_test)

print('Test loss:', test_loss)
print('Test accuracy:', test_acc)

# Make predictions on the test set
predictions = model.predict(X_test)

# Display a random image from the test set along with its predicted and actual
    ↪labels
random_index = np.random.randint(0, len(X_test))
plt.imshow(X_test[random_index].reshape((28, 28)), cmap='gray')
plt.title("Predicted label: " + str(np.argmax(predictions[random_index])) + ",
    ↪Actual label: " + str(y_test[random_index]))
plt.show()

```

```

Epoch 1/200
25/25 [=====] - 1s 19ms/step - loss: 2.2846 - accuracy:
0.1925 - val_loss: 2.2486 - val_accuracy: 0.3800
Epoch 2/200
25/25 [=====] - 0s 14ms/step - loss: 2.1759 - accuracy:
0.4250 - val_loss: 2.0537 - val_accuracy: 0.6050
Epoch 3/200
25/25 [=====] - 0s 13ms/step - loss: 1.8563 - accuracy:
0.6112 - val_loss: 1.6137 - val_accuracy: 0.6700
Epoch 4/200
25/25 [=====] - 0s 12ms/step - loss: 1.3655 - accuracy:
0.6488 - val_loss: 1.1698 - val_accuracy: 0.6050
Epoch 5/200
25/25 [=====] - 0s 14ms/step - loss: 0.9896 - accuracy:
0.7475 - val_loss: 0.7824 - val_accuracy: 0.8500
Epoch 6/200
25/25 [=====] - 0s 13ms/step - loss: 0.7536 - accuracy:
0.7962 - val_loss: 0.6027 - val_accuracy: 0.8350
Epoch 7/200
25/25 [=====] - 0s 14ms/step - loss: 0.5874 - accuracy:
0.8350 - val_loss: 0.4533 - val_accuracy: 0.8950
Epoch 8/200

```

25/25 [=====] - 0s 13ms/step - loss: 0.4757 - accuracy:  
0.8838 - val\_loss: 0.3707 - val\_accuracy: 0.9050  
Epoch 9/200  
25/25 [=====] - 0s 13ms/step - loss: 0.4206 - accuracy:  
0.8775 - val\_loss: 0.3054 - val\_accuracy: 0.9000  
Epoch 10/200  
25/25 [=====] - 0s 12ms/step - loss: 0.3453 - accuracy:  
0.9137 - val\_loss: 0.2720 - val\_accuracy: 0.9100  
Epoch 11/200  
25/25 [=====] - 0s 12ms/step - loss: 0.3013 - accuracy:  
0.9187 - val\_loss: 0.2270 - val\_accuracy: 0.9550  
Epoch 12/200  
25/25 [=====] - 0s 13ms/step - loss: 0.2726 - accuracy:  
0.9200 - val\_loss: 0.2044 - val\_accuracy: 0.9500  
Epoch 13/200  
25/25 [=====] - 0s 11ms/step - loss: 0.2399 - accuracy:  
0.9450 - val\_loss: 0.1830 - val\_accuracy: 0.9500  
Epoch 14/200  
25/25 [=====] - 0s 13ms/step - loss: 0.2200 - accuracy:  
0.9375 - val\_loss: 0.1682 - val\_accuracy: 0.9500  
Epoch 15/200  
25/25 [=====] - 0s 14ms/step - loss: 0.1997 - accuracy:  
0.9450 - val\_loss: 0.1454 - val\_accuracy: 0.9550  
Epoch 16/200  
25/25 [=====] - 0s 13ms/step - loss: 0.1911 - accuracy:  
0.9525 - val\_loss: 0.1517 - val\_accuracy: 0.9700  
Epoch 17/200  
25/25 [=====] - 0s 12ms/step - loss: 0.1754 - accuracy:  
0.9475 - val\_loss: 0.1296 - val\_accuracy: 0.9500  
Epoch 18/200  
25/25 [=====] - 0s 12ms/step - loss: 0.1507 - accuracy:  
0.9625 - val\_loss: 0.1355 - val\_accuracy: 0.9600  
Epoch 19/200  
25/25 [=====] - 0s 19ms/step - loss: 0.1725 - accuracy:  
0.9513 - val\_loss: 0.1259 - val\_accuracy: 0.9400  
Epoch 20/200  
25/25 [=====] - 0s 18ms/step - loss: 0.1383 - accuracy:  
0.9613 - val\_loss: 0.1176 - val\_accuracy: 0.9550  
Epoch 21/200  
25/25 [=====] - 0s 17ms/step - loss: 0.1330 - accuracy:  
0.9600 - val\_loss: 0.1169 - val\_accuracy: 0.9550  
Epoch 22/200  
25/25 [=====] - 0s 18ms/step - loss: 0.1232 - accuracy:  
0.9650 - val\_loss: 0.1053 - val\_accuracy: 0.9550  
Epoch 23/200  
25/25 [=====] - 0s 20ms/step - loss: 0.1044 - accuracy:  
0.9663 - val\_loss: 0.1022 - val\_accuracy: 0.9600  
Epoch 24/200

25/25 [=====] - 0s 19ms/step - loss: 0.1028 - accuracy:  
0.9750 - val\_loss: 0.0994 - val\_accuracy: 0.9600  
Epoch 25/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0980 - accuracy:  
0.9725 - val\_loss: 0.0974 - val\_accuracy: 0.9550  
Epoch 26/200  
25/25 [=====] - 1s 22ms/step - loss: 0.0945 - accuracy:  
0.9725 - val\_loss: 0.1052 - val\_accuracy: 0.9650  
Epoch 27/200  
25/25 [=====] - 0s 20ms/step - loss: 0.0935 - accuracy:  
0.9787 - val\_loss: 0.0901 - val\_accuracy: 0.9600  
Epoch 28/200  
25/25 [=====] - 0s 18ms/step - loss: 0.1102 - accuracy:  
0.9663 - val\_loss: 0.0809 - val\_accuracy: 0.9700  
Epoch 29/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0859 - accuracy:  
0.9750 - val\_loss: 0.0946 - val\_accuracy: 0.9400  
Epoch 30/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0683 - accuracy:  
0.9812 - val\_loss: 0.0932 - val\_accuracy: 0.9700  
Epoch 31/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0704 - accuracy:  
0.9850 - val\_loss: 0.0795 - val\_accuracy: 0.9600  
Epoch 32/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0643 - accuracy:  
0.9850 - val\_loss: 0.0829 - val\_accuracy: 0.9650  
Epoch 33/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0685 - accuracy:  
0.9775 - val\_loss: 0.0761 - val\_accuracy: 0.9700  
Epoch 34/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0548 - accuracy:  
0.9862 - val\_loss: 0.0821 - val\_accuracy: 0.9700  
Epoch 35/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0611 - accuracy:  
0.9875 - val\_loss: 0.0714 - val\_accuracy: 0.9750  
Epoch 36/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0524 - accuracy:  
0.9912 - val\_loss: 0.0782 - val\_accuracy: 0.9650  
Epoch 37/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0477 - accuracy:  
0.9900 - val\_loss: 0.0853 - val\_accuracy: 0.9550  
Epoch 38/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0533 - accuracy:  
0.9875 - val\_loss: 0.0894 - val\_accuracy: 0.9550  
Epoch 39/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0478 - accuracy:  
0.9900 - val\_loss: 0.0658 - val\_accuracy: 0.9800  
Epoch 40/200



25/25 [=====] - 0s 12ms/step - loss: 0.0486 - accuracy:  
 0.9862 - val\_loss: 0.0657 - val\_accuracy: 0.9650  
 Epoch 41/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0404 - accuracy:  
 0.9900 - val\_loss: 0.0647 - val\_accuracy: 0.9750  
 Epoch 42/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0377 - accuracy:  
 0.9937 - val\_loss: 0.0645 - val\_accuracy: 0.9750  
 Epoch 43/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0357 - accuracy:  
 0.9937 - val\_loss: 0.0645 - val\_accuracy: 0.9650  
 Epoch 44/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0352 - accuracy:  
 0.9925 - val\_loss: 0.0597 - val\_accuracy: 0.9800  
 Epoch 45/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0345 - accuracy:  
 0.9937 - val\_loss: 0.0725 - val\_accuracy: 0.9650  
 Epoch 46/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0404 - accuracy:  
 0.9887 - val\_loss: 0.0724 - val\_accuracy: 0.9700  
 Epoch 47/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0293 - accuracy:  
 0.9962 - val\_loss: 0.0935 - val\_accuracy: 0.9550  
 Epoch 48/200  
 25/25 [=====] - 0s 11ms/step - loss: 0.0373 - accuracy:  
 0.9887 - val\_loss: 0.0601 - val\_accuracy: 0.9650  
 Epoch 49/200  
 25/25 [=====] - 1s 24ms/step - loss: 0.0291 - accuracy:  
 0.9937 - val\_loss: 0.0582 - val\_accuracy: 0.9750  
 Epoch 50/200  
 25/25 [=====] - 1s 22ms/step - loss: 0.0246 - accuracy:  
 0.9975 - val\_loss: 0.0642 - val\_accuracy: 0.9750  
 Epoch 51/200  
 25/25 [=====] - 1s 22ms/step - loss: 0.0272 - accuracy:  
 0.9975 - val\_loss: 0.0633 - val\_accuracy: 0.9700  
 Epoch 52/200  
 25/25 [=====] - 1s 24ms/step - loss: 0.0225 - accuracy:  
 0.9975 - val\_loss: 0.0647 - val\_accuracy: 0.9750  
 Epoch 53/200  
 25/25 [=====] - 1s 20ms/step - loss: 0.0262 - accuracy:  
 0.9937 - val\_loss: 0.0551 - val\_accuracy: 0.9750  
 Epoch 54/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0233 - accuracy:  
 0.9950 - val\_loss: 0.0642 - val\_accuracy: 0.9750  
 Epoch 55/200  
 25/25 [=====] - 0s 17ms/step - loss: 0.0199 - accuracy:  
 0.9987 - val\_loss: 0.0524 - val\_accuracy: 0.9800  
 Epoch 56/200

25/25 [=====] - 1s 20ms/step - loss: 0.0245 - accuracy:  
 0.9950 - val\_loss: 0.0674 - val\_accuracy: 0.9700  
 Epoch 57/200  
 25/25 [=====] - 1s 49ms/step - loss: 0.0170 - accuracy:  
 0.9962 - val\_loss: 0.0573 - val\_accuracy: 0.9750  
 Epoch 58/200  
 25/25 [=====] - 1s 28ms/step - loss: 0.0169 - accuracy:  
 0.9987 - val\_loss: 0.0616 - val\_accuracy: 0.9700  
 Epoch 59/200  
 25/25 [=====] - 0s 19ms/step - loss: 0.0196 - accuracy:  
 1.0000 - val\_loss: 0.0611 - val\_accuracy: 0.9700  
 Epoch 60/200  
 25/25 [=====] - 0s 18ms/step - loss: 0.0176 - accuracy:  
 0.9975 - val\_loss: 0.0535 - val\_accuracy: 0.9800  
 Epoch 61/200  
 25/25 [=====] - 0s 18ms/step - loss: 0.0153 - accuracy:  
 0.9975 - val\_loss: 0.0502 - val\_accuracy: 0.9700  
 Epoch 62/200  
 25/25 [=====] - 0s 19ms/step - loss: 0.0145 - accuracy:  
 0.9975 - val\_loss: 0.0483 - val\_accuracy: 0.9800  
 Epoch 63/200  
 25/25 [=====] - 0s 20ms/step - loss: 0.0134 - accuracy:  
 1.0000 - val\_loss: 0.0540 - val\_accuracy: 0.9700  
 Epoch 64/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0124 - accuracy:  
 1.0000 - val\_loss: 0.0486 - val\_accuracy: 0.9700  
 Epoch 65/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0126 - accuracy:  
 1.0000 - val\_loss: 0.0530 - val\_accuracy: 0.9800  
 Epoch 66/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0107 - accuracy:  
 1.0000 - val\_loss: 0.0481 - val\_accuracy: 0.9800  
 Epoch 67/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0097 - accuracy:  
 1.0000 - val\_loss: 0.0514 - val\_accuracy: 0.9750  
 Epoch 68/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0102 - accuracy:  
 1.0000 - val\_loss: 0.0509 - val\_accuracy: 0.9750  
 Epoch 69/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0124 - accuracy:  
 1.0000 - val\_loss: 0.0480 - val\_accuracy: 0.9850  
 Epoch 70/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0158 - accuracy:  
 0.9975 - val\_loss: 0.0511 - val\_accuracy: 0.9800  
 Epoch 71/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0118 - accuracy:  
 0.9987 - val\_loss: 0.0527 - val\_accuracy: 0.9750  
 Epoch 72/200

25/25 [=====] - 0s 15ms/step - loss: 0.0100 - accuracy:  
1.0000 - val\_loss: 0.0523 - val\_accuracy: 0.9750  
Epoch 73/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0089 - accuracy:  
1.0000 - val\_loss: 0.0542 - val\_accuracy: 0.9750  
Epoch 74/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0107 - accuracy:  
0.9987 - val\_loss: 0.0498 - val\_accuracy: 0.9750  
Epoch 75/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0096 - accuracy:  
0.9987 - val\_loss: 0.0477 - val\_accuracy: 0.9750  
Epoch 76/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0089 - accuracy:  
0.9987 - val\_loss: 0.0539 - val\_accuracy: 0.9650  
Epoch 77/200  
25/25 [=====] - 0s 11ms/step - loss: 0.0097 - accuracy:  
0.9987 - val\_loss: 0.0449 - val\_accuracy: 0.9800  
Epoch 78/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0176 - accuracy:  
0.9962 - val\_loss: 0.0587 - val\_accuracy: 0.9750  
Epoch 79/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0108 - accuracy:  
0.9987 - val\_loss: 0.0550 - val\_accuracy: 0.9800  
Epoch 80/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0088 - accuracy:  
0.9987 - val\_loss: 0.0535 - val\_accuracy: 0.9800  
Epoch 81/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0066 - accuracy:  
1.0000 - val\_loss: 0.0520 - val\_accuracy: 0.9750  
Epoch 82/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0090 - accuracy:  
0.9987 - val\_loss: 0.0550 - val\_accuracy: 0.9800  
Epoch 83/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0094 - accuracy:  
0.9987 - val\_loss: 0.0517 - val\_accuracy: 0.9750  
Epoch 84/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0097 - accuracy:  
1.0000 - val\_loss: 0.0561 - val\_accuracy: 0.9800  
Epoch 85/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0071 - accuracy:  
1.0000 - val\_loss: 0.0554 - val\_accuracy: 0.9800  
Epoch 86/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0060 - accuracy:  
1.0000 - val\_loss: 0.0515 - val\_accuracy: 0.9800  
Epoch 87/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0061 - accuracy:  
1.0000 - val\_loss: 0.0555 - val\_accuracy: 0.9800  
Epoch 88/200

25/25 [=====] - 0s 14ms/step - loss: 0.0060 - accuracy:  
1.0000 - val\_loss: 0.0498 - val\_accuracy: 0.9850  
Epoch 89/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0071 - accuracy:  
1.0000 - val\_loss: 0.0525 - val\_accuracy: 0.9700  
Epoch 90/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0076 - accuracy:  
1.0000 - val\_loss: 0.0504 - val\_accuracy: 0.9750  
Epoch 91/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0047 - accuracy:  
1.0000 - val\_loss: 0.0450 - val\_accuracy: 0.9750  
Epoch 92/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0050 - accuracy:  
1.0000 - val\_loss: 0.0542 - val\_accuracy: 0.9750  
Epoch 93/200  
25/25 [=====] - 1s 20ms/step - loss: 0.0047 - accuracy:  
1.0000 - val\_loss: 0.0434 - val\_accuracy: 0.9800  
Epoch 94/200  
25/25 [=====] - 0s 18ms/step - loss: 0.0063 - accuracy:  
0.9987 - val\_loss: 0.0468 - val\_accuracy: 0.9800  
Epoch 95/200  
25/25 [=====] - 0s 20ms/step - loss: 0.0047 - accuracy:  
1.0000 - val\_loss: 0.0481 - val\_accuracy: 0.9800  
Epoch 96/200  
25/25 [=====] - 0s 20ms/step - loss: 0.0043 - accuracy:  
1.0000 - val\_loss: 0.0542 - val\_accuracy: 0.9700  
Epoch 97/200  
25/25 [=====] - 1s 20ms/step - loss: 0.0043 - accuracy:  
1.0000 - val\_loss: 0.0532 - val\_accuracy: 0.9700  
Epoch 98/200  
25/25 [=====] - 1s 20ms/step - loss: 0.0060 - accuracy:  
0.9987 - val\_loss: 0.0639 - val\_accuracy: 0.9650  
Epoch 99/200  
25/25 [=====] - 0s 18ms/step - loss: 0.0042 - accuracy:  
1.0000 - val\_loss: 0.0638 - val\_accuracy: 0.9750  
Epoch 100/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0041 - accuracy:  
1.0000 - val\_loss: 0.0519 - val\_accuracy: 0.9800  
Epoch 101/200  
25/25 [=====] - 1s 20ms/step - loss: 0.0035 - accuracy:  
1.0000 - val\_loss: 0.0500 - val\_accuracy: 0.9800  
Epoch 102/200  
25/25 [=====] - 1s 21ms/step - loss: 0.0035 - accuracy:  
1.0000 - val\_loss: 0.0584 - val\_accuracy: 0.9700  
Epoch 103/200  
25/25 [=====] - 0s 13ms/step - loss: 0.0044 - accuracy:  
1.0000 - val\_loss: 0.0442 - val\_accuracy: 0.9800  
Epoch 104/200

25/25 [=====] - 0s 13ms/step - loss: 0.0051 - accuracy:  
 1.0000 - val\_loss: 0.0393 - val\_accuracy: 0.9800  
 Epoch 105/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0053 - accuracy:  
 1.0000 - val\_loss: 0.0548 - val\_accuracy: 0.9700  
 Epoch 106/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0056 - accuracy:  
 0.9987 - val\_loss: 0.0644 - val\_accuracy: 0.9650  
 Epoch 107/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0043 - accuracy:  
 1.0000 - val\_loss: 0.0457 - val\_accuracy: 0.9700  
 Epoch 108/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0029 - accuracy:  
 1.0000 - val\_loss: 0.0506 - val\_accuracy: 0.9800  
 Epoch 109/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0031 - accuracy:  
 1.0000 - val\_loss: 0.0585 - val\_accuracy: 0.9700  
 Epoch 110/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0028 - accuracy:  
 1.0000 - val\_loss: 0.0449 - val\_accuracy: 0.9800  
 Epoch 111/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0026 - accuracy:  
 1.0000 - val\_loss: 0.0538 - val\_accuracy: 0.9750  
 Epoch 112/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0026 - accuracy:  
 1.0000 - val\_loss: 0.0557 - val\_accuracy: 0.9750  
 Epoch 113/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0025 - accuracy:  
 1.0000 - val\_loss: 0.0593 - val\_accuracy: 0.9750  
 Epoch 114/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0037 - accuracy:  
 1.0000 - val\_loss: 0.0476 - val\_accuracy: 0.9800  
 Epoch 115/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0024 - accuracy:  
 1.0000 - val\_loss: 0.0534 - val\_accuracy: 0.9700  
 Epoch 116/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0026 - accuracy:  
 1.0000 - val\_loss: 0.0438 - val\_accuracy: 0.9850  
 Epoch 117/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0031 - accuracy:  
 1.0000 - val\_loss: 0.0494 - val\_accuracy: 0.9800  
 Epoch 118/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0032 - accuracy:  
 1.0000 - val\_loss: 0.0528 - val\_accuracy: 0.9800  
 Epoch 119/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0023 - accuracy:  
 1.0000 - val\_loss: 0.0460 - val\_accuracy: 0.9750  
 Epoch 120/200

25/25 [=====] - 0s 16ms/step - loss: 0.0029 - accuracy:  
 1.0000 - val\_loss: 0.0366 - val\_accuracy: 0.9850  
 Epoch 121/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0020 - accuracy:  
 1.0000 - val\_loss: 0.0532 - val\_accuracy: 0.9700  
 Epoch 122/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0026 - accuracy:  
 1.0000 - val\_loss: 0.0501 - val\_accuracy: 0.9800  
 Epoch 123/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0022 - accuracy:  
 1.0000 - val\_loss: 0.0505 - val\_accuracy: 0.9800  
 Epoch 124/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0022 - accuracy:  
 1.0000 - val\_loss: 0.0469 - val\_accuracy: 0.9850  
 Epoch 125/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0024 - accuracy:  
 1.0000 - val\_loss: 0.0482 - val\_accuracy: 0.9750  
 Epoch 126/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0027 - accuracy:  
 1.0000 - val\_loss: 0.0684 - val\_accuracy: 0.9750  
 Epoch 127/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0020 - accuracy:  
 1.0000 - val\_loss: 0.0565 - val\_accuracy: 0.9750  
 Epoch 128/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0021 - accuracy:  
 1.0000 - val\_loss: 0.0557 - val\_accuracy: 0.9800  
 Epoch 129/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0020 - accuracy:  
 1.0000 - val\_loss: 0.0472 - val\_accuracy: 0.9800  
 Epoch 130/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0017 - accuracy:  
 1.0000 - val\_loss: 0.0494 - val\_accuracy: 0.9800  
 Epoch 131/200  
 25/25 [=====] - 0s 18ms/step - loss: 0.0014 - accuracy:  
 1.0000 - val\_loss: 0.0429 - val\_accuracy: 0.9800  
 Epoch 132/200  
 25/25 [=====] - 1s 21ms/step - loss: 0.0017 - accuracy:  
 1.0000 - val\_loss: 0.0528 - val\_accuracy: 0.9750  
 Epoch 133/200  
 25/25 [=====] - 1s 21ms/step - loss: 0.0021 - accuracy:  
 1.0000 - val\_loss: 0.0447 - val\_accuracy: 0.9850  
 Epoch 134/200  
 25/25 [=====] - 0s 18ms/step - loss: 0.0018 - accuracy:  
 1.0000 - val\_loss: 0.0560 - val\_accuracy: 0.9700  
 Epoch 135/200  
 25/25 [=====] - 1s 20ms/step - loss: 0.0041 - accuracy:  
 0.9987 - val\_loss: 0.0436 - val\_accuracy: 0.9800  
 Epoch 136/200

25/25 [=====] - 1s 20ms/step - loss: 0.0016 - accuracy:  
1.0000 - val\_loss: 0.0440 - val\_accuracy: 0.9850  
Epoch 137/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0013 - accuracy:  
1.0000 - val\_loss: 0.0474 - val\_accuracy: 0.9800  
Epoch 138/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0013 - accuracy:  
1.0000 - val\_loss: 0.0564 - val\_accuracy: 0.9750  
Epoch 139/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0016 - accuracy:  
1.0000 - val\_loss: 0.0538 - val\_accuracy: 0.9750  
Epoch 140/200  
25/25 [=====] - 0s 19ms/step - loss: 0.0012 - accuracy:  
1.0000 - val\_loss: 0.0551 - val\_accuracy: 0.9750  
Epoch 141/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0015 - accuracy:  
1.0000 - val\_loss: 0.0595 - val\_accuracy: 0.9750  
Epoch 142/200  
25/25 [=====] - 0s 12ms/step - loss: 0.0020 - accuracy:  
1.0000 - val\_loss: 0.0400 - val\_accuracy: 0.9800  
Epoch 143/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0016 - accuracy:  
1.0000 - val\_loss: 0.0484 - val\_accuracy: 0.9800  
Epoch 144/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0016 - accuracy:  
1.0000 - val\_loss: 0.0559 - val\_accuracy: 0.9750  
Epoch 145/200  
25/25 [=====] - 0s 17ms/step - loss: 0.0015 - accuracy:  
1.0000 - val\_loss: 0.0594 - val\_accuracy: 0.9700  
Epoch 146/200  
25/25 [=====] - 1s 27ms/step - loss: 0.0014 - accuracy:  
1.0000 - val\_loss: 0.0568 - val\_accuracy: 0.9700  
Epoch 147/200  
25/25 [=====] - 1s 30ms/step - loss: 0.0014 - accuracy:  
1.0000 - val\_loss: 0.0436 - val\_accuracy: 0.9800  
Epoch 148/200  
25/25 [=====] - 1s 22ms/step - loss: 0.0011 - accuracy:  
1.0000 - val\_loss: 0.0450 - val\_accuracy: 0.9800  
Epoch 149/200  
25/25 [=====] - 1s 26ms/step - loss: 0.0021 - accuracy:  
1.0000 - val\_loss: 0.0555 - val\_accuracy: 0.9750  
Epoch 150/200  
25/25 [=====] - 1s 26ms/step - loss: 0.0015 - accuracy:  
1.0000 - val\_loss: 0.0415 - val\_accuracy: 0.9800  
Epoch 151/200  
25/25 [=====] - 1s 30ms/step - loss: 0.0014 - accuracy:  
1.0000 - val\_loss: 0.0562 - val\_accuracy: 0.9700  
Epoch 152/200

25/25 [=====] - 1s 26ms/step - loss: 0.0011 - accuracy:  
 1.0000 - val\_loss: 0.0439 - val\_accuracy: 0.9800  
 Epoch 153/200  
 25/25 [=====] - 1s 29ms/step - loss: 0.0024 - accuracy:  
 1.0000 - val\_loss: 0.0585 - val\_accuracy: 0.9850  
 Epoch 154/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0017 - accuracy:  
 1.0000 - val\_loss: 0.0434 - val\_accuracy: 0.9850  
 Epoch 155/200  
 25/25 [=====] - 0s 15ms/step - loss: 9.1182e-04 -  
 accuracy: 1.0000 - val\_loss: 0.0378 - val\_accuracy: 0.9800  
 Epoch 156/200  
 25/25 [=====] - 0s 16ms/step - loss: 0.0013 - accuracy:  
 1.0000 - val\_loss: 0.0509 - val\_accuracy: 0.9750  
 Epoch 157/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0031 - accuracy:  
 0.9987 - val\_loss: 0.0659 - val\_accuracy: 0.9750  
 Epoch 158/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0019 - accuracy:  
 1.0000 - val\_loss: 0.0561 - val\_accuracy: 0.9800  
 Epoch 159/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0014 - accuracy:  
 1.0000 - val\_loss: 0.0506 - val\_accuracy: 0.9850  
 Epoch 160/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0013 - accuracy:  
 1.0000 - val\_loss: 0.0544 - val\_accuracy: 0.9800  
 Epoch 161/200  
 25/25 [=====] - 0s 16ms/step - loss: 0.0011 - accuracy:  
 1.0000 - val\_loss: 0.0513 - val\_accuracy: 0.9800  
 Epoch 162/200  
 25/25 [=====] - 1s 20ms/step - loss: 0.0013 - accuracy:  
 1.0000 - val\_loss: 0.0624 - val\_accuracy: 0.9750  
 Epoch 163/200  
 25/25 [=====] - 1s 20ms/step - loss: 0.0025 - accuracy:  
 1.0000 - val\_loss: 0.0546 - val\_accuracy: 0.9750  
 Epoch 164/200  
 25/25 [=====] - 0s 19ms/step - loss: 0.0017 - accuracy:  
 1.0000 - val\_loss: 0.0449 - val\_accuracy: 0.9800  
 Epoch 165/200  
 25/25 [=====] - 0s 19ms/step - loss: 0.0028 - accuracy:  
 1.0000 - val\_loss: 0.0607 - val\_accuracy: 0.9750  
 Epoch 166/200  
 25/25 [=====] - 1s 20ms/step - loss: 0.0017 - accuracy:  
 1.0000 - val\_loss: 0.0483 - val\_accuracy: 0.9850  
 Epoch 167/200  
 25/25 [=====] - 0s 19ms/step - loss: 0.0022 - accuracy:  
 1.0000 - val\_loss: 0.0520 - val\_accuracy: 0.9850  
 Epoch 168/200



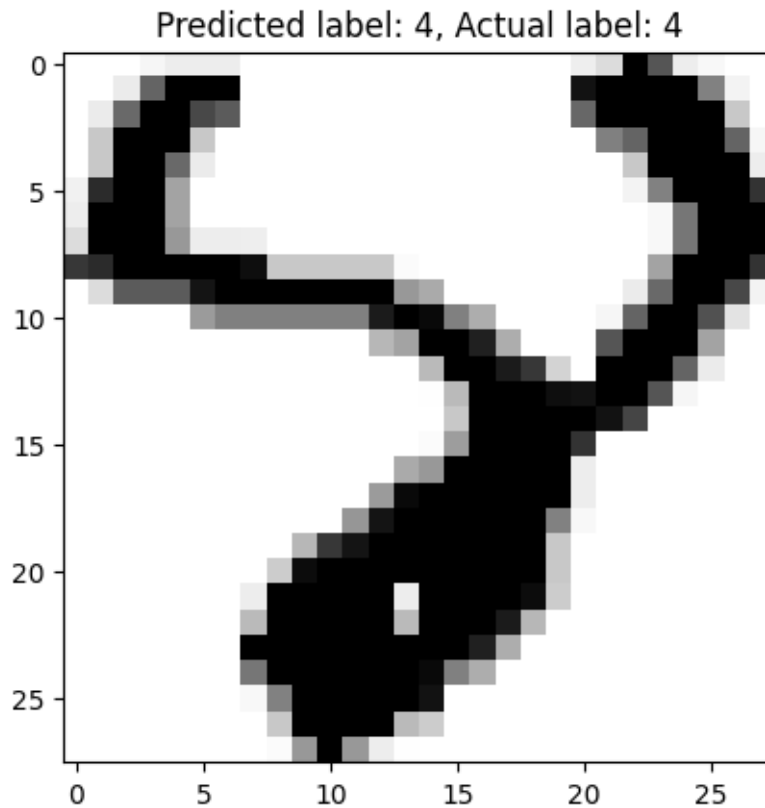
25/25 [=====] - 0s 20ms/step - loss: 0.0011 - accuracy: 1.0000 - val\_loss: 0.0414 - val\_accuracy: 0.9850  
Epoch 169/200  
25/25 [=====] - 1s 21ms/step - loss: 8.3109e-04 - accuracy: 1.0000 - val\_loss: 0.0478 - val\_accuracy: 0.9800  
Epoch 170/200  
25/25 [=====] - 1s 21ms/step - loss: 9.8751e-04 - accuracy: 1.0000 - val\_loss: 0.0386 - val\_accuracy: 0.9850  
Epoch 171/200  
25/25 [=====] - 0s 18ms/step - loss: 0.0016 - accuracy: 1.0000 - val\_loss: 0.0625 - val\_accuracy: 0.9700  
Epoch 172/200  
25/25 [=====] - 0s 15ms/step - loss: 0.0019 - accuracy: 1.0000 - val\_loss: 0.0557 - val\_accuracy: 0.9850  
Epoch 173/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0010 - accuracy: 1.0000 - val\_loss: 0.0557 - val\_accuracy: 0.9750  
Epoch 174/200  
25/25 [=====] - 0s 15ms/step - loss: 6.5068e-04 - accuracy: 1.0000 - val\_loss: 0.0515 - val\_accuracy: 0.9700  
Epoch 175/200  
25/25 [=====] - 0s 14ms/step - loss: 8.6378e-04 - accuracy: 1.0000 - val\_loss: 0.0555 - val\_accuracy: 0.9850  
Epoch 176/200  
25/25 [=====] - 0s 14ms/step - loss: 0.0011 - accuracy: 1.0000 - val\_loss: 0.0562 - val\_accuracy: 0.9850  
Epoch 177/200  
25/25 [=====] - 0s 15ms/step - loss: 6.0633e-04 - accuracy: 1.0000 - val\_loss: 0.0588 - val\_accuracy: 0.9750  
Epoch 178/200  
25/25 [=====] - 0s 15ms/step - loss: 6.0414e-04 - accuracy: 1.0000 - val\_loss: 0.0547 - val\_accuracy: 0.9750  
Epoch 179/200  
25/25 [=====] - 0s 14ms/step - loss: 5.4845e-04 - accuracy: 1.0000 - val\_loss: 0.0545 - val\_accuracy: 0.9800  
Epoch 180/200  
25/25 [=====] - 0s 14ms/step - loss: 9.9580e-04 - accuracy: 1.0000 - val\_loss: 0.0370 - val\_accuracy: 0.9800  
Epoch 181/200  
25/25 [=====] - 0s 13ms/step - loss: 5.3931e-04 - accuracy: 1.0000 - val\_loss: 0.0478 - val\_accuracy: 0.9850  
Epoch 182/200  
25/25 [=====] - 0s 12ms/step - loss: 5.4727e-04 - accuracy: 1.0000 - val\_loss: 0.0518 - val\_accuracy: 0.9800  
Epoch 183/200  
25/25 [=====] - 0s 15ms/step - loss: 4.6698e-04 - accuracy: 1.0000 - val\_loss: 0.0578 - val\_accuracy: 0.9750  
Epoch 184/200

25/25 [=====] - 0s 14ms/step - loss: 0.0016 - accuracy:  
 1.0000 - val\_loss: 0.0528 - val\_accuracy: 0.9700  
 Epoch 185/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0022 - accuracy:  
 1.0000 - val\_loss: 0.0262 - val\_accuracy: 0.9850  
 Epoch 186/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0044 - accuracy:  
 0.9987 - val\_loss: 0.0380 - val\_accuracy: 0.9750  
 Epoch 187/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0064 - accuracy:  
 0.9975 - val\_loss: 0.0582 - val\_accuracy: 0.9750  
 Epoch 188/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0259 - accuracy:  
 0.9950 - val\_loss: 0.1166 - val\_accuracy: 0.9700  
 Epoch 189/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0184 - accuracy:  
 0.9937 - val\_loss: 0.0758 - val\_accuracy: 0.9650  
 Epoch 190/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0123 - accuracy:  
 0.9962 - val\_loss: 0.0574 - val\_accuracy: 0.9700  
 Epoch 191/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0125 - accuracy:  
 0.9962 - val\_loss: 0.0632 - val\_accuracy: 0.9800  
 Epoch 192/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0153 - accuracy:  
 0.9962 - val\_loss: 0.1283 - val\_accuracy: 0.9550  
 Epoch 193/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0044 - accuracy:  
 0.9987 - val\_loss: 0.0373 - val\_accuracy: 0.9850  
 Epoch 194/200  
 25/25 [=====] - 0s 13ms/step - loss: 0.0014 - accuracy:  
 1.0000 - val\_loss: 0.0573 - val\_accuracy: 0.9750  
 Epoch 195/200  
 25/25 [=====] - 0s 13ms/step - loss: 8.6838e-04 -  
 accuracy: 1.0000 - val\_loss: 0.0567 - val\_accuracy: 0.9800  
 Epoch 196/200  
 25/25 [=====] - 0s 12ms/step - loss: 0.0012 - accuracy:  
 1.0000 - val\_loss: 0.0493 - val\_accuracy: 0.9850  
 Epoch 197/200  
 25/25 [=====] - 0s 15ms/step - loss: 0.0033 - accuracy:  
 0.9987 - val\_loss: 0.0639 - val\_accuracy: 0.9850  
 Epoch 198/200  
 25/25 [=====] - 0s 14ms/step - loss: 0.0021 - accuracy:  
 1.0000 - val\_loss: 0.0405 - val\_accuracy: 0.9800  
 Epoch 199/200  
 25/25 [=====] - 0s 17ms/step - loss: 9.2678e-04 -  
 accuracy: 1.0000 - val\_loss: 0.0348 - val\_accuracy: 0.9850  
 Epoch 200/200

```

25/25 [=====] - 1s 20ms/step - loss: 0.0011 - accuracy:
1.0000 - val_loss: 0.0412 - val_accuracy: 0.9700
6/6 [=====] - 0s 7ms/step - loss: 0.2929 - accuracy:
0.9607
Test loss: 0.2928925156593323
Test accuracy: 0.9606741666793823
6/6 [=====] - 0s 6ms/step

```



```

[ ]: from sklearn.metrics import confusion_matrix
import seaborn as sns

```

### Model Evaluation Test Data On Neural Network Built from Scratch

```

[ ]: dev_predictions = make_predictions(X_dev, W1, b1, W2, b2)
print("Accuracy", get_accuracy(dev_predictions, Y_dev))
# Generate confusion matrix and heatmap
conf_matrix = confusion_matrix(dev_predictions, Y_dev)
print("conf_matrix : ", "\n")
print(conf_matrix, "\n")
# Set the color palette
sns.set_palette("PuBu")

```

```
# Create the heatmap
sns.heatmap(conf_matrix, annot=True, cmap="PuBu", fmt="d")

plt.xlabel('Predicted Label')
plt.ylabel('True Label')
plt.show()
```

```
#####
#####
```

```
[4.16696672e-14 1.80837842e-13 2.67292175e-07 ... 1.36800138e-08
 5.54959792e-09 8.03985953e-14]
[6.26792105e-05 1.31990060e-04 9.92806716e-01 ... 1.64616787e-06
 9.99207935e-01 6.54667153e-11]
[9.96133000e-01 9.99657979e-01 2.07972362e-10 ... 8.34260092e-13
 1.24098336e-05 1.30871302e-09]
...
[2.84065691e-12 3.17700440e-13 4.70040117e-10 ... 1.19442321e-08
 8.09826572e-05 6.74908182e-11]
[9.78391782e-09 1.23190207e-14 1.72053496e-05 ... 5.84675007e-03
 6.64936549e-15 1.03299375e-03]
[5.63315199e-09 1.11241770e-10 6.85217404e-03 ... 6.43741570e-01
 3.21839156e-05 3.93302527e-08]]
[2 2 1 1 4 4 1 9 8 8 2 5 0 1 8 3 9 8 7 9 9 0 8 6 7 8 9 7 6 2 7 6 8 0 7 0 4
 8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
 4 5 4 0 1 7 6 9 1 2 5 8 6 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 7 1 9 0 3
 4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 4 2 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6
 6 4 7 4 2 3 1 9 0 7 8 0 6 5 3 3 6 8 8 8 7 8 7 9 2 4 9 9 1 5]
[2 2 1 1 4 4 1 9 8 8 2 5 0 1 8 3 9 8 7 9 9 0 8 6 7 8 9 7 6 2 7 6 8 0 7 0 4
 8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
 4 5 4 0 1 7 6 9 1 2 5 8 6 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 7 1 9 0 3
 4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 4 2 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6
 6 4 7 4 2 3 1 9 0 7 8 0 6 5 3 3 6 8 8 8 7 8 7 9 2 4 9 9 1 5] [2 2 1 1 4 4 1 2 8
8 2 0 0 1 8 3 9 8 1 8 9 0 8 6 7 8 9 1 6 2 7 6 8 0 7 0 4
 8 5 5 4 6 7 2 7 0 6 5 7 6 2 3 5 3 5 5 3 3 4 4 4 5 6 4 5 3 0 3 2 5 6 6 6 4
 4 5 4 0 1 7 6 9 1 2 2 8 3 1 5 0 7 2 3 9 5 4 7 5 9 9 8 6 9 9 0 3 1 7 9 0 3
 4 9 6 0 9 5 2 5 5 8 0 3 3 1 7 2 2 3 9 4 0 7 9 9 5 4 7 9 8 0 0 1 6 3 1 1 6
 6 4 7 4 2 3 1 9 0 7 8 0 6 1 3 2 6 8 8 8 7 8 7 9 2 4 9 9 7 5]
```

Accuracy 0.9213483146067416

conf\_matrix :

```
[[17  0  0  0  0  0  0  0  0  0]
 [ 0 12  0  0  0  0  0  2  0  0]
 [ 0  0 13  1  0  0  0  0  0  0]
 [ 0  0  1 15  0  0  0  0  0  0]
 [ 0  0  1  0 18  0  0  0  0  0]
 [ 1  1  1  0  0 18  0  0  0  0]
 [ 0  0  0  1  0  0 18  0  0  0]
```

```
[ 0  3  0  0  0  0  0 16  0  0]
[ 0  0  0  0  0  0  0  0 17  0]
[ 0  0  1  0  0  0  0  0  1 20]]
```

