In [42]:
```
import numpy as np
import tensorflow as tf
from tensorflow import keras
import pandas as pd
from matplotlib import pyplot as plt
%matplotlib inline
import os
import cv2
from keras.layers import Dense, Flatten
```

In [2]:
```
# Define the paths to your image folders
train_path = 'C:\\Users\\biraj\\OneDrive\\PythonProjects\\Machine learning neural network\\'
val_path = 'C:\\Users\\biraj\\OneDrive\\PythonProjects\\Machine learning neural network\\'
```

In [3]:
```
# Set the path to the folder containing the 'train' folder
data_dir = train_path


# Set the image size
img_size = (32, 32)

# Create empty lists for the images and labels
images = []
labels = []

# Loop over each folder from '0' to '9'
for label in range(10):
    folder_path = os.path.join(data_dir, 'train', str(label))
    # Loop over each image in the folder
    for file in os.listdir(folder_path):
        file_path = os.path.join(folder_path, file)
        if file_path.endswith(('.tiff','.bmp')):
            # Load the image and resize it to the desired size
            img = cv2.imread(file_path, cv2.IMREAD_GRAYSCALE)
            img = cv2.resize(img, img_size)
            # Append the image and label to the lists
            images.append(img)
            labels.append(label)

# Convert the lists to NumPy arrays
```

```
images = np.array(images)
labels = np.array(labels)

# Save the arrays in NumPy format
np.save('x_train.npy', images)
np.save('y_train.npy', labels)
```

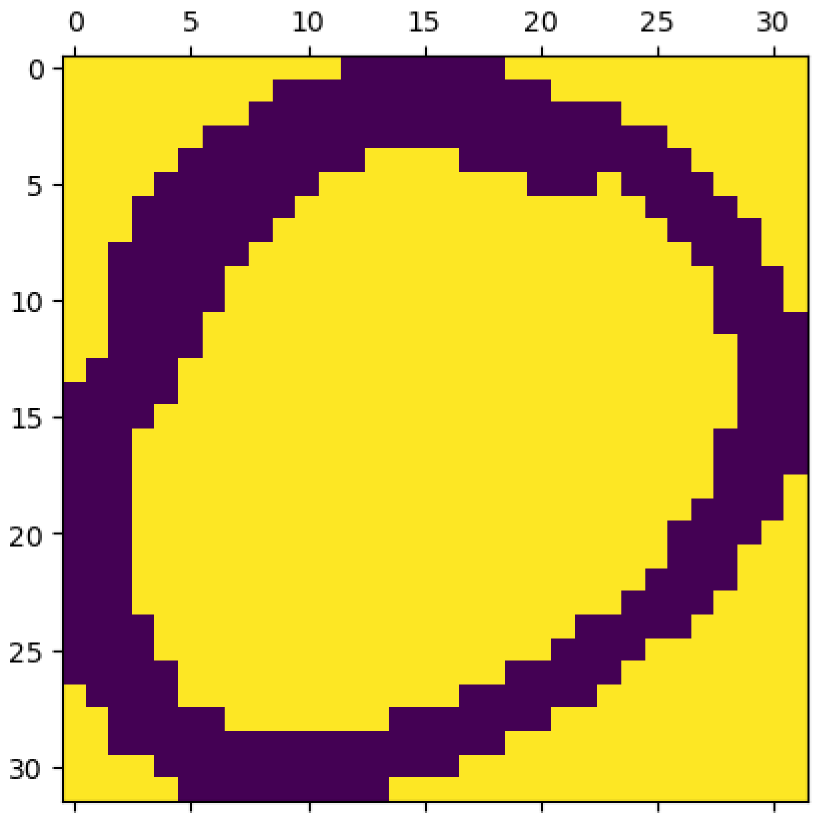
In [56]:
```
# Set the path to the folder containing the 'val' folder
data_dir_val = val_path

# Set the image size
img_size_val = (32, 32)

# Create empty lists for the images and labels
images_val = []
labels_val = []

# Loop over each folder from '0' to '9'
for label in range(10):
    folder_path = os.path.join(data_dir_val, 'val\\', str(label))

    # Loop over each image in the folder
    for file in os.listdir(folder_path):
        file_path = os.path.join(folder_path, file)
        if file_path.endswith(('.tiff','.bmp')):
            # Load the image and resize it to the desired size
            img = cv2.imread(file_path, cv2.IMREAD_GRAYSCALE)
            img = cv2.resize(img, img_size_val)
            # Append the image and label to the lists
            images_val.append(img)
            labels_val.append(label)

# Convert the lists to NumPy arrays
images_val = np.array(images_val)
labels_val = np.array(labels_val)

# Save the arrays in NumPy format
np.save('x_test.npy', images_val)
np.save('y_test.npy', labels_val)
```

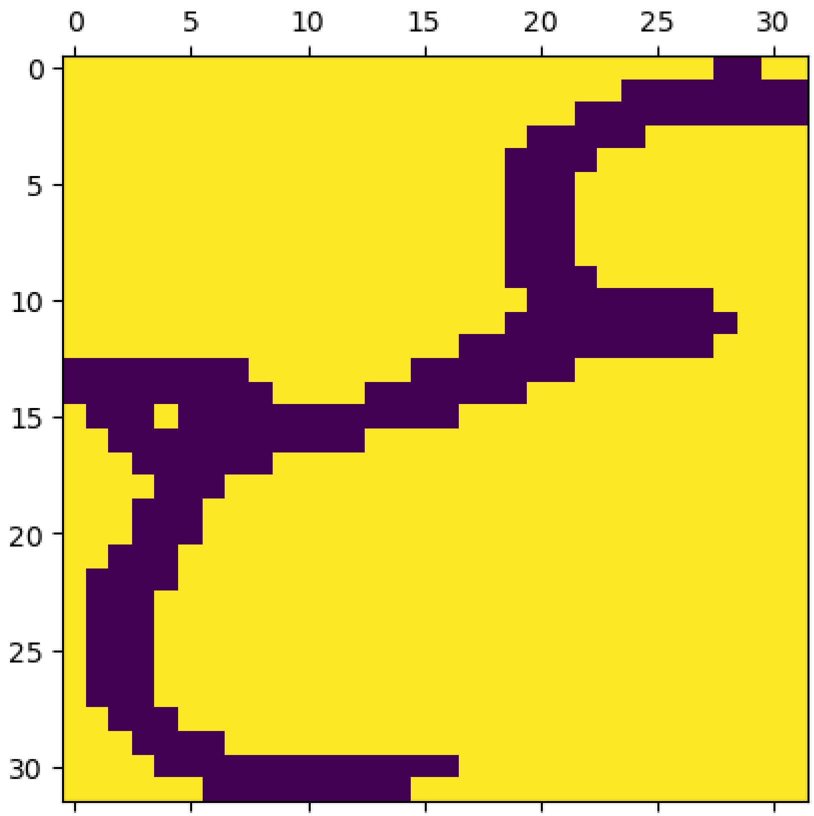
In [82]:
```
# Load the dataset
x_train = np.load('x_train.npy')
y_train = np.load('y_train.npy')
x_test = np.load('x_test.npy')
y_test = np.load('y_test.npy')
```

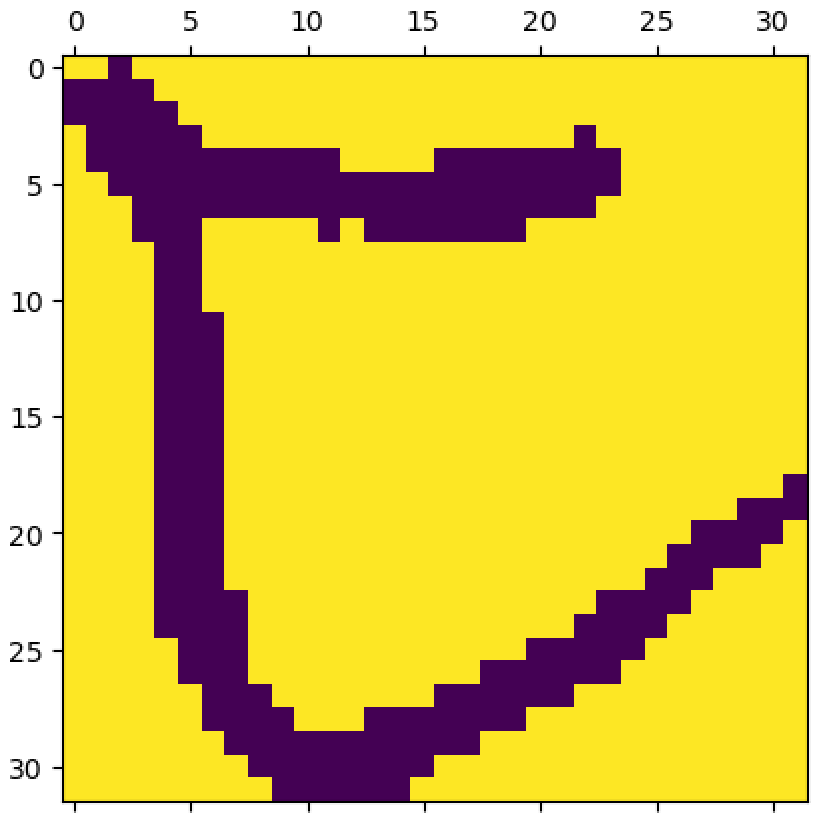
In [83]:
```
# test the images are loaded correctly

print(len(x_train))
print(len(x_test))
x_train[0].shape
x_train[0]
plt.matshow(x_train[0])
plt.matshow(x_train[999])
print(x_train.shape)
print(x_test.shape)
y_train
y_test
plt.matshow(x_test[150])
```

```
1000
178
(1000, 32, 32)
(178, 32, 32)
```

Out[83]:
```
<matplotlib.image.AxesImage at 0x20ba468abb0>
```


0
5
10
15
20
25
30
0
5
10
15
20
25
30


0
5
10
15
20
25
30



In [84]:

```
# # flatten the dataset i.e, change 2D to 1D (skipped this , and flattened in the model)

# x_train_flat = x_train.reshape(len(x_train),32*32)
# x_test_flat = x_test.reshape(len(x_test),32*32)

# print(x_train_flat.shape)
# print(x_test_flat.shape)

# x_train_flat[0]
```

In [85]:

```
# creating a simple nn
# create a dense layer where every input is connected to every other output, the number of inputs are 1000, outputs are 10
# activation function is sigmoid

model = keras.Sequential([
    keras.layers.Flatten(),
```

```
    keras.layers.Dense(10, input_shape=(1024,),activation = 'sigmoid')
])

# compile the nn
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy']
             )
# train the model
# some 10 iterations done here
model.fit(x_train, y_train,epochs= 10, validation_data=(x_test, y_test))
```

```
Epoch 1/10
32/32 [==============================] - 1s 13ms/step - loss: 172.8362 - accuracy: 0.3560 - val_loss: 54.1465 - val_accuracy: 0.
5899
Epoch 2/10
32/32 [==============================] - 0s 6ms/step - loss: 21.8444 - accuracy: 0.7990 - val_loss: 37.7204 - val_accuracy: 0.73
03
Epoch 3/10
32/32 [==============================] - 0s 6ms/step - loss: 14.4273 - accuracy: 0.8600 - val_loss: 33.3826 - val_accuracy: 0.76
40
Epoch 4/10
32/32 [==============================] - 0s 5ms/step - loss: 8.5064 - accuracy: 0.9100 - val_loss: 21.0088 - val_accuracy: 0.809
0
Epoch 5/10
32/32 [==============================] - 0s 5ms/step - loss: 6.6391 - accuracy: 0.9110 - val_loss: 21.1726 - val_accuracy: 0.809
0
Epoch 6/10
32/32 [==============================] - 0s 5ms/step - loss: 3.2933 - accuracy: 0.9510 - val_loss: 13.3256 - val_accuracy: 0.904
5
Epoch 7/10
32/32 [==============================] - 0s 5ms/step - loss: 1.9723 - accuracy: 0.9710 - val_loss: 16.6435 - val_accuracy: 0.837
1
Epoch 8/10
32/32 [==============================] - 0s 5ms/step - loss: 1.8374 - accuracy: 0.9650 - val_loss: 16.0006 - val_accuracy: 0.848
3
Epoch 9/10
32/32 [==============================] - 0s 5ms/step - loss: 6.0564 - accuracy: 0.9380 - val_loss: 13.9050 - val_accuracy: 0.893
3
Epoch 10/10
32/32 [==============================] - 0s 5ms/step - loss: 2.2400 - accuracy: 0.9710 - val_loss: 19.2359 - val_accuracy: 0.882
0
```

Out[85]:
```
<keras.callbacks.History at 0x20ba7a2ee20>
```

In [86]:
```
# Observation : we see a better accuracy from the 2nd iteration
```

In [87]:
```
#  now scale and try to check the accuracy, divide dataset by 255

x_train_scaled = x_train/255
x_test_scaled = x_test/255

model.fit(x_train_scaled, y_train,epochs= 10, validation_data=(x_test_scaled, y_test))
```

```
Epoch 1/10
32/32 [==============================] - 1s 13ms/step - loss: 0.7792 - accuracy: 0.9040 - val_loss: 1.0426 - val_accuracy: 0.786
5
Epoch 2/10
32/32 [==============================] - 0s 5ms/step - loss: 0.7721 - accuracy: 0.8990 - val_loss: 0.9965 - val_accuracy: 0.8202
Epoch 3/10
32/32 [==============================] - 0s 5ms/step - loss: 0.7343 - accuracy: 0.9380 - val_loss: 0.9635 - val_accuracy: 0.8596
Epoch 4/10
32/32 [==============================] - 0s 5ms/step - loss: 0.7079 - accuracy: 0.9630 - val_loss: 0.9408 - val_accuracy: 0.9045
Epoch 5/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6901 - accuracy: 0.9760 - val_loss: 0.9264 - val_accuracy: 0.9157
Epoch 6/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6772 - accuracy: 0.9860 - val_loss: 0.9150 - val_accuracy: 0.9213
Epoch 7/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6671 - accuracy: 0.9860 - val_loss: 0.9070 - val_accuracy: 0.9270
Epoch 8/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6584 - accuracy: 0.9910 - val_loss: 0.8993 - val_accuracy: 0.9213
Epoch 9/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6513 - accuracy: 0.9920 - val_loss: 0.8931 - val_accuracy: 0.9157
Epoch 10/10
32/32 [==============================] - 0s 5ms/step - loss: 0.6446 - accuracy: 0.9920 - val_loss: 0.8866 - val_accuracy: 0.9213
```

Out[87]:
```
<keras.callbacks.History at 0x20ba3f89ca0>
```

In [21]:
```
# Observation : we got better result for all iterations on scaling the training dataset
```

In [88]:
```
# evaluate test dataset

model.evaluate(x_test_scaled,y_test)
```

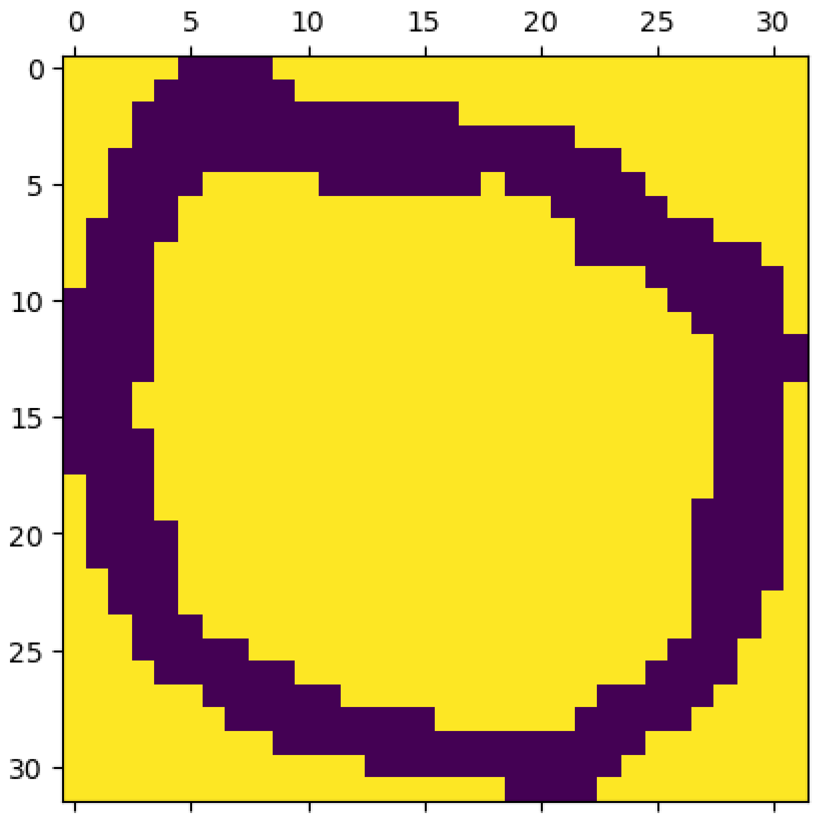
```
6/6 [==============================] - 0s 4ms/step - loss: 0.8866 - accuracy: 0.9213
```

Out[88]:
```
[0.8866074681282043, 0.9213483333587646]
```

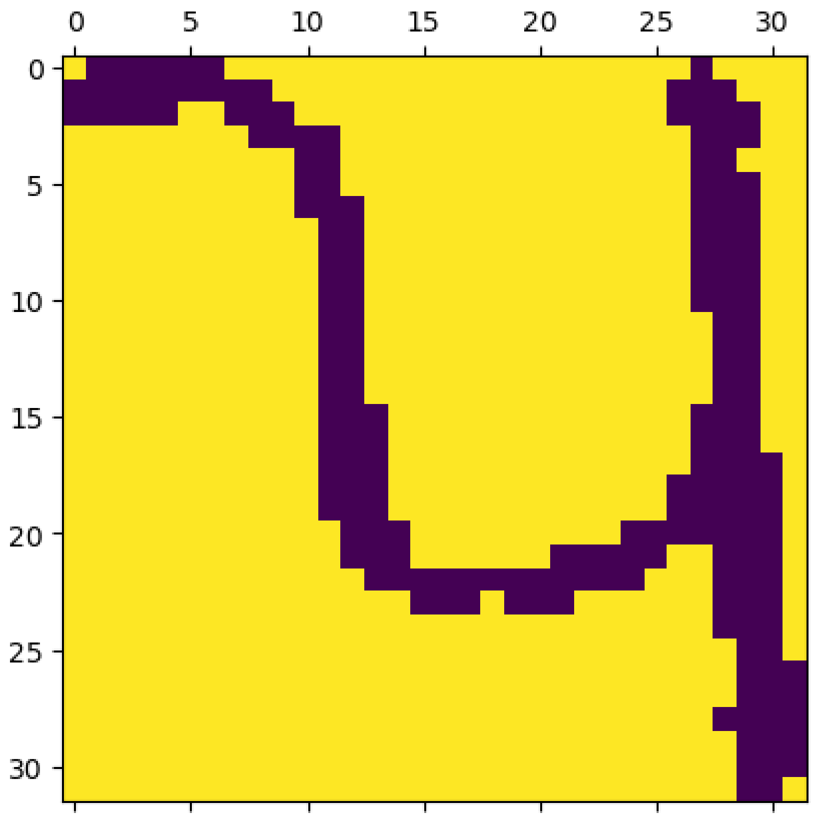
In [23]:
```
# Observation : result almost same as the training dataset,
```

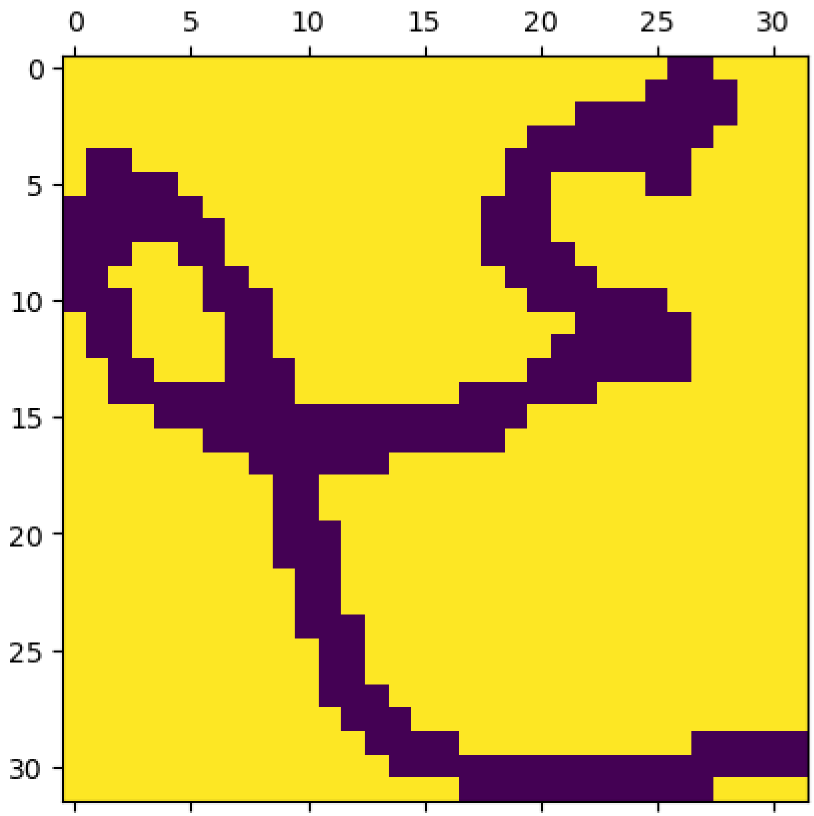
In [90]:
```
# predict 1st image

plt.matshow(x_test[0])

y_predicted = model.predict(x_test_scaled)
y_predicted[0]

# this showing the 10 results for the input '0', we need to look for the value which is max

print('Predicted Value is ',np.argmax(y_predicted[0]))

# test some more values

plt.matshow(x_test[88])
print('Predicted Value is ',np.argmax(y_predicted[88]))

plt.matshow(x_test[177])
print('Predicted Value is ',np.argmax(y_predicted[177]))
```

```
6/6 [==============================] - 0s 3ms/step
Predicted Value is  0
Predicted Value is  5
Predicted Value is  9
```



0 5 10 15 20 25 30
0 5 10 15 20 25 30


0
5
10
15
20
25
30
0
5
10
15
20
25
30



In [91]:

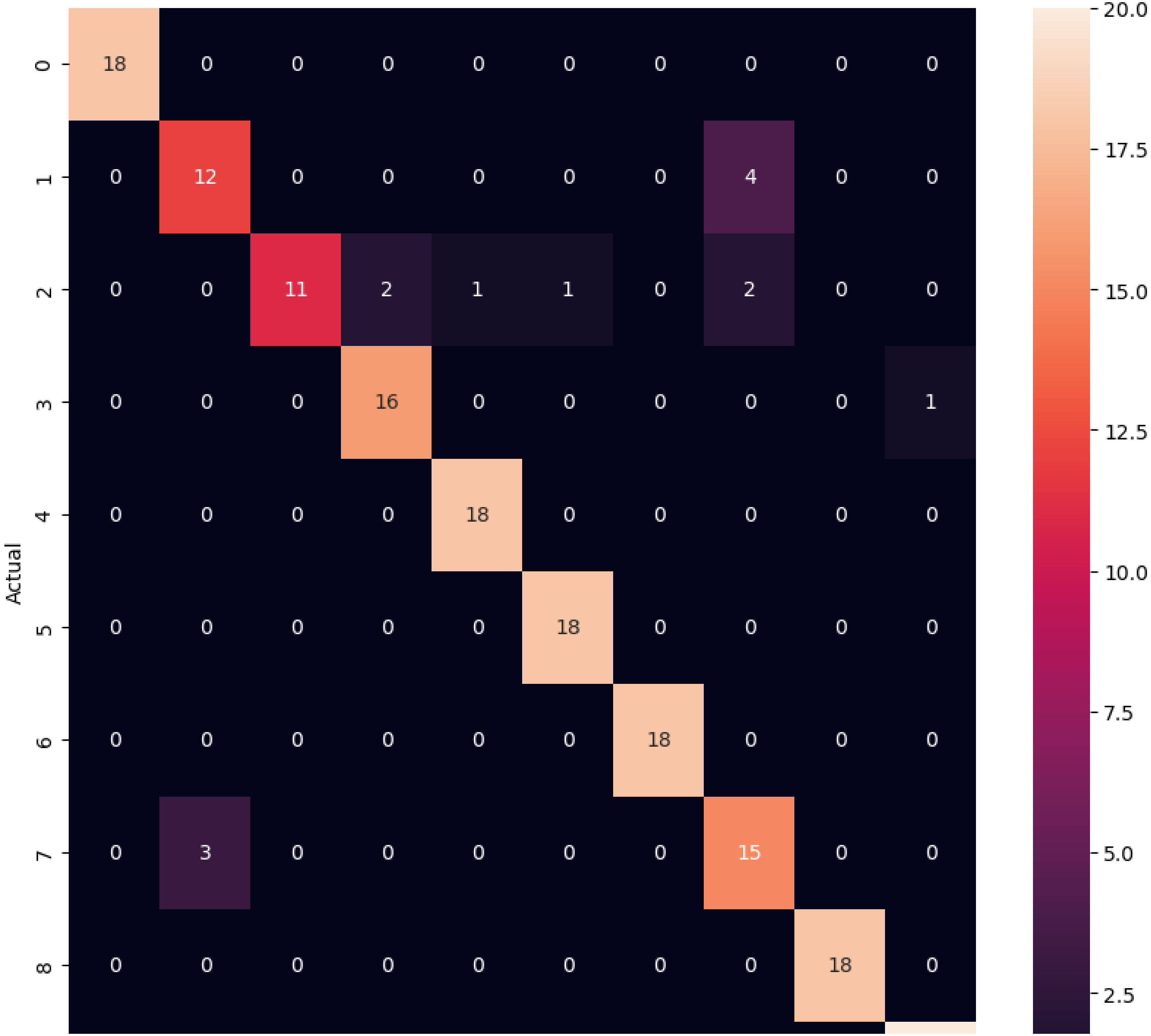
```
# some predictions may not be not right

# build confusion matrix to see how our prediction looks like

# convert to concrete values
y_predicted_labels=[np.argmax(i) for i in y_predicted]

print(y_predicted_labels, len(y_predicted_labels))

conf_mat = tf.math.confusion_matrix(labels=y_test, predictions=y_predicted_labels)
conf_mat
```

```
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 7, 1, 1, 1, 1, 1, 1, 1, 1, 7, 1, 7, 1, 1, 7, 2, 2, 7, 2, 2, 2, 2, 3,
2, 2, 2, 2, 3, 4, 7, 2, 5, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 9, 3, 3, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4,
4, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 1, 7, 7, 7, 7, 7,
7, 7, 7, 7, 1, 7, 7, 7, 7, 7, 1, 7, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9,
9, 9, 9, 9, 9, 9, 9] 178
```

Out[91]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[18,  0,  0,  0,  0,  0,  0,  0,  0,  0],
       [ 0, 12,  0,  0,  0,  0,  0,  4,  0,  0],
       [ 0,  0, 11,  2,  1,  1,  0,  2,  0,  0],
       [ 0,  0,  0, 16,  0,  0,  0,  0,  0,  1],
       [ 0,  0,  0,  0, 18,  0,  0,  0,  0,  0],
       [ 0,  0,  0,  0,  0, 18,  0,  0,  0,  0],
       [ 0,  0,  0,  0,  0,  0, 18,  0,  0,  0],
       [ 0,  3,  0,  0,  0,  0,  0, 15,  0,  0],
       [ 0,  0,  0,  0,  0,  0,  0,  0, 18,  0],
       [ 0,  0,  0,  0,  0,  0,  0,  0,  0, 20]])>
```

In [92]:
```
import seaborn as sn
plt.figure(figsize = (10,10))
sn.heatmap(conf_mat,annot=True,fmt='d')
plt.xlabel('Predicted')
plt.ylabel('Actual')
```

Out[92]:
```
Text(95.72222222222221, 0.5, 'Actual')
```



Actual
0
1
2
3
4
5
6
7
8
18 0 0 0 0 0 0 0 0 0
0 12 0 0 0 0 0 4 0 0
0 0 11 2 1 1 0 2 0 0
0 0 0 16 0 0 0 0 0 1
0 0 0 0 18 0 0 0 0 0
0 0 0 0 0 18 0 0 0 0
0 0 0 0 0 0 18 0 0 0
0 3 0 0 0 0 0 15 0 0
0 0 0 0 0 0 0 0 18 0
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5

In [28]:
```
# here we can see there are some errors
# we need to modify our nn, we add some layers in the above model and different activation function
```

In [116…
```
# in 1st Dense layer,the input is 32 x 32 = 1024 neurons, which will give 10 output(numbers from 0 to 9)
# 2nd Dense layer,the input is 10 neurons from above layers output
# we can add more layers for accuracy

model2 = keras.Sequential([
    keras.layers.Flatten(),
    keras.layers.Dense(1024,input_shape=(1024,), activation='relu'),
    keras.layers.Dense(10, activation='softmax')
])

# compile the nn
model2.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy']
             )
# train the model
# some 10 iterations done here
history = model2.fit(x_train_scaled, y_train,epochs= 10, validation_data=(x_test_scaled, y_test))
```

```
Epoch 1/10
32/32 [==============================] - 1s 22ms/step - loss: 1.3086 - accuracy: 0.6980 - val_loss: 0.4044 - val_accuracy: 0.898
9
Epoch 2/10
32/32 [==============================] - 0s 14ms/step - loss: 0.1836 - accuracy: 0.9430 - val_loss: 0.3402 - val_accuracy: 0.915
7
Epoch 3/10
32/32 [==============================] - 0s 14ms/step - loss: 0.1347 - accuracy: 0.9550 - val_loss: 0.3611 - val_accuracy: 0.882
0
Epoch 4/10
32/32 [==============================] - 0s 14ms/step - loss: 0.0675 - accuracy: 0.9840 - val_loss: 0.2386 - val_accuracy: 0.938
2
Epoch 5/10
32/32 [==============================] - 0s 14ms/step - loss: 0.0567 - accuracy: 0.9830 - val_loss: 0.2717 - val_accuracy: 0.938
2
Epoch 6/10
32/32 [==============================] - 0s 14ms/step - loss: 0.0523 - accuracy: 0.9860 - val_loss: 0.3067 - val_accuracy: 0.932
6
Epoch 7/10
32/32 [==============================] - 1s 16ms/step - loss: 0.0499 - accuracy: 0.9860 - val_loss: 0.1749 - val_accuracy: 0.949
4
Epoch 8/10
32/32 [==============================] - 0s 15ms/step - loss: 0.0553 - accuracy: 0.9840 - val_loss: 0.3237 - val_accuracy: 0.870
8
Epoch 9/10
32/32 [==============================] - 1s 16ms/step - loss: 0.0239 - accuracy: 0.9950 - val_loss: 0.2086 - val_accuracy: 0.943
8
Epoch 10/10
32/32 [==============================] - 0s 15ms/step - loss: 0.0129 - accuracy: 0.9990 - val_loss: 0.1806 - val_accuracy: 0.960
7
```

In [117…

```
# Observation : due to multiple layers the compiling will take more time to execute
# we also got amazing accuracy than earlier

# evaluate test dataset on modified model

model2.evaluate(x_test_scaled,y_test)
```

```
6/6 [==============================] - 0s 5ms/step - loss: 0.1806 - accuracy: 0.9607
```

Out[117]:

```
[0.18058674037456512, 0.9606741666793823]
```

In [118…

```
# Earlier we got  0.9213483333587646 now we got 0.9606741666793823 accuracy
```

```
# redo the confusion matrix

# build confusion matrix to see how our prediction looks like

# convert to concrete values

y_predicted = model2.predict(x_test_scaled)
y_predicted[0]

y_predicted_labels=[np.argmax(i) for i in y_predicted]

print(y_predicted_labels, len(y_predicted_labels))

conf_mat = tf.math.confusion_matrix(labels=y_test, predictions=y_predicted_labels)
conf_mat
```

```
6/6 [==============================] - 0s 5ms/step
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 7, 1, 1, 1, 7, 1, 2, 2, 2, 2, 2, 2, 2, 2,
2, 2, 2, 2, 9, 4, 2, 2, 5, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4,
4, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 6, 1, 7, 7, 7, 7, 7,
7, 7, 7, 7, 1, 7, 7, 7, 7, 7, 7, 7, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9, 9,
9, 9, 9, 9, 9, 9, 9] 178
```

Out[118]:

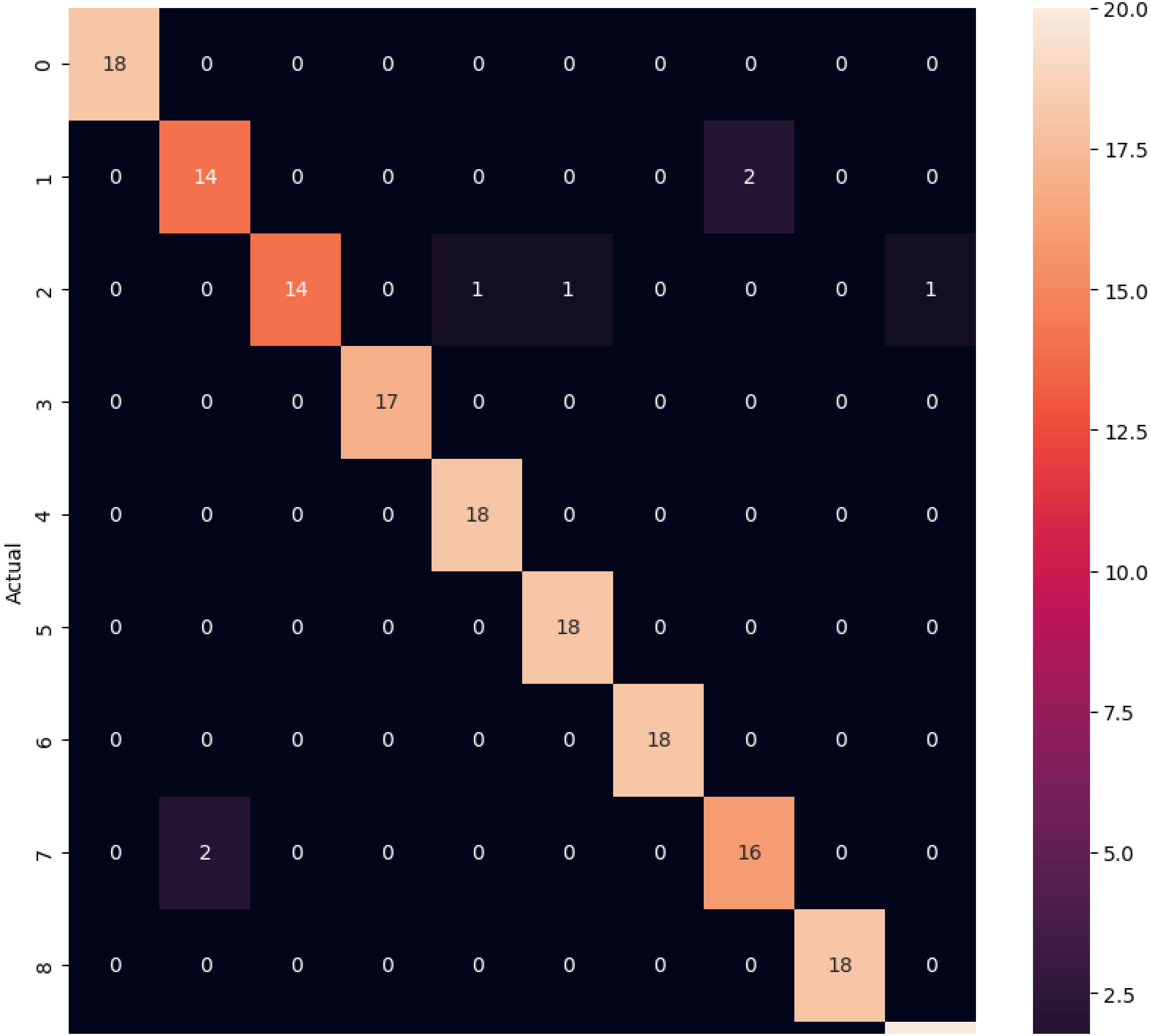
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[18,  0,  0,  0,  0,  0,  0,  0,  0,  0],
       [ 0, 14,  0,  0,  0,  0,  0,  2,  0,  0],
       [ 0,  0, 14,  0,  1,  1,  0,  0,  0,  1],
       [ 0,  0,  0, 17,  0,  0,  0,  0,  0,  0],
       [ 0,  0,  0,  0, 18,  0,  0,  0,  0,  0],
       [ 0,  0,  0,  0,  0, 18,  0,  0,  0,  0],
       [ 0,  0,  0,  0,  0,  0, 18,  0,  0,  0],
       [ 0,  2,  0,  0,  0,  0,  0, 16,  0,  0],
       [ 0,  0,  0,  0,  0,  0,  0,  0, 18,  0],
       [ 0,  0,  0,  0,  0,  0,  0,  0,  0, 20]])>
```

In [119…

```
plt.figure(figsize = (10,10))
sn.heatmap(conf_mat,annot=True,fmt='d')
plt.xlabel('Predicted')
plt.ylabel('Actual')
```

Out[119]:

```
Text(95.72222222222221, 0.5, 'Actual')
```


Actual
0
1
2
3
4
5
6
7
8
18 0 0 0 0 0 0 0 0 0
0 14 0 0 0 0 0 2 0 0
0 0 14 0 1 1 0 0 0 1
0 0 0 17 0 0 0 0 0 0
0 0 0 0 18 0 0 0 0 0
0 0 0 0 0 18 0 0 0 0
0 0 0 0 0 0 18 0 0 0
0 2 0 0 0 0 0 16 0 0
0 0 0 0 0 0 0 0 18 0
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5

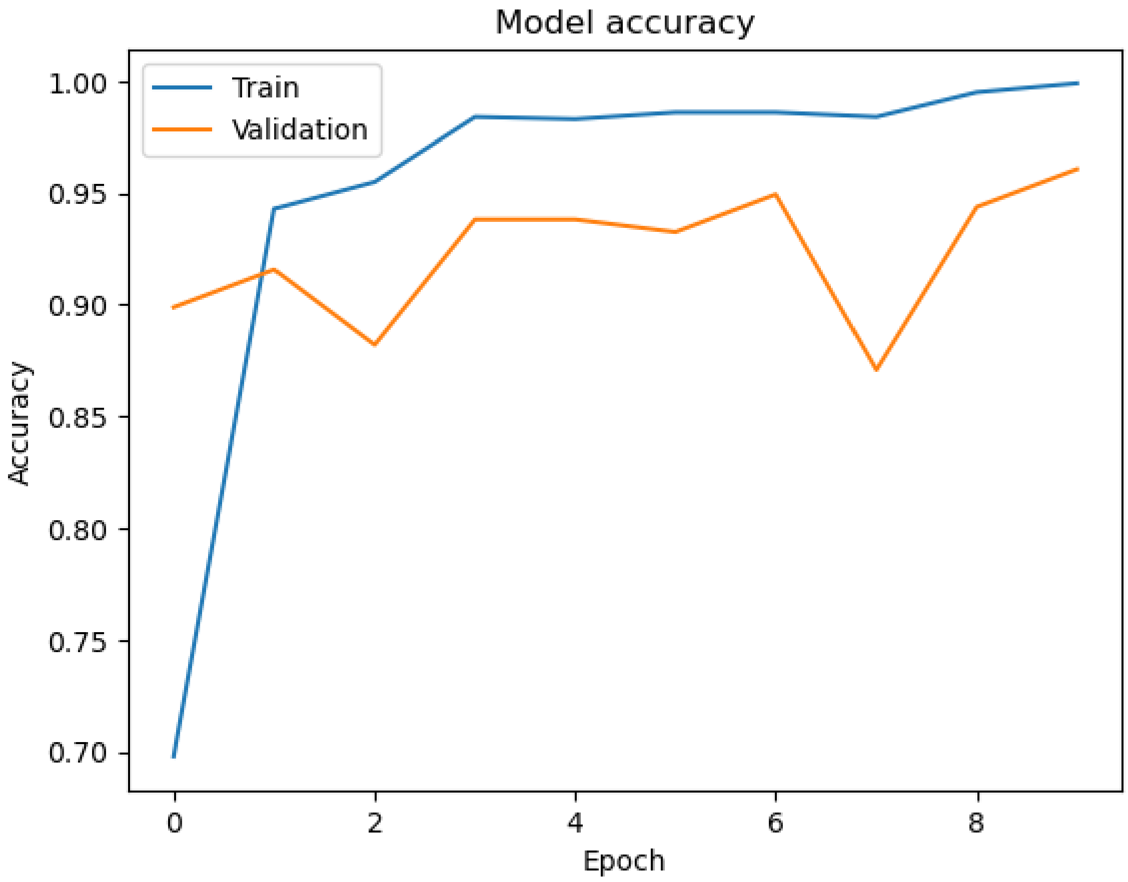
In [106…

```
# Observatoin : we see in the updated model, there are less number of errors,
# whatever is not in diagonal is a error
```

In [120…

```

# Evaluate the model
test_loss, test_acc = model.evaluate(x_test, y_test)
print('Test accuracy:', test_acc)

# Plot the training and validation accuracy
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```

```
6/6 [==============================] - 0s 14ms/step - loss: 27.9263 - accuracy: 0.9719
Test accuracy: 0.9719101190567017
```



Model accuracy
Train
Validation
Accuracy
1.00
0.95
0.90
0.85
0.80
0.75
0.70
Epoch
0
2
4
6
8

In [ ]: