In [ ]:
```
                                        #ml-assignment-frac3-m22ai608#
```

In [49]:
```
#Learning to implement Neural Network
#Gurmukhi Handwritten Digit Classification: Gurmukhi is one of the popularIndian scripts widely used in Indian state of Punjab. In this part of the assignment,our goal is to de

#Dataset link
#Modify the code provided in here and a video tutorial here, and develop a robustneural network to classify the Gurmukhi digits. Higher performance on test set willhave bonus p
```

In [1]:
```
#Importing Libraries
import numpy as np
import pandas as pd
from matplotlib import pyplot as plt
%matplotlib inline
import cv2
import os
from keras.layers import Dense, Flatten
import tensorflow as tf
from tensorflow import keras
```

In [15]:
```
from keras.datasets import mnist
```

In [2]:
```
train_path = "C:\\Users\\Admin\\Downloads"
train_path
```

Out[2]:
```
'C:\\Users\\Admin\\Downloads'
```

In [3]:
```
val_path="C:\\Users\\Admin\\Downloads"
val_path
```

Out[3]:
```
'C:\\Users\\Admin\\Downloads'
```

In [4]:
```
# Set the path to the folder containing the 'train' folder
data_directory = train_path
# Set the image size
img_size = (32, 32)
# Create empty lists for the images and labels
images = []
labels = []
```

In [5]:
```
# Loop over each folder from '0' to '9'
for label in range(10):
    folder_path = os.path.join(data_directory, '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)
```

In [6]:
```python
# 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 [7]:
```python
print(images,labels)
```

...

In [8]:
```python
# 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_values = []
labels_values = []
```

In [9]:
```python
# Loop over each folder from '0' to '9'
for label in range(10):
    folder_path=os.path.join(data_directory,'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)
            #append the image and label to the lists
            images_values.append(img)
            labels_values.append(label)
```

In [11]:
```python
# Convert the lists to NumPy arrays
images_values = np.array(images_values)
labels_values = np.array(labels_values)
# Save the arrays in NumPy format
np.save('x_test.npy', images_values)
np.save('y_test.npy', labels_values)
```

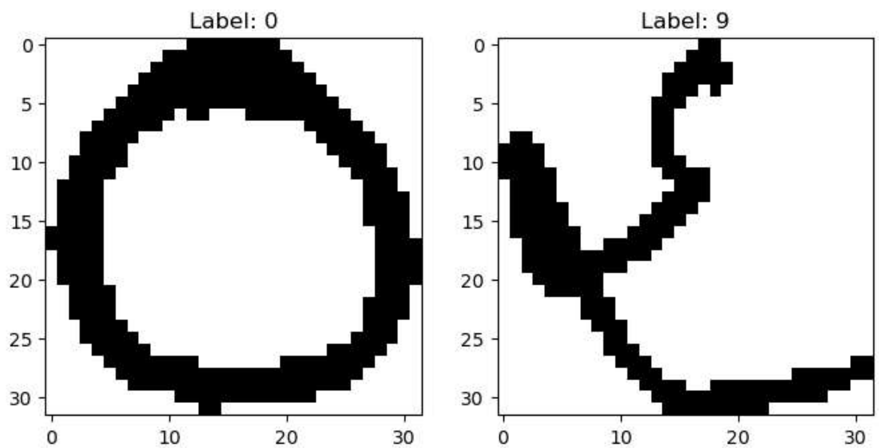
In [12]:
```python
# Load the dataset
x_train = np.load('x_train.npy')
y_train = np.load('y_train.npy')
x_test = np.load('x_test.npy')
y_test = np.load('y_test.npy')
```

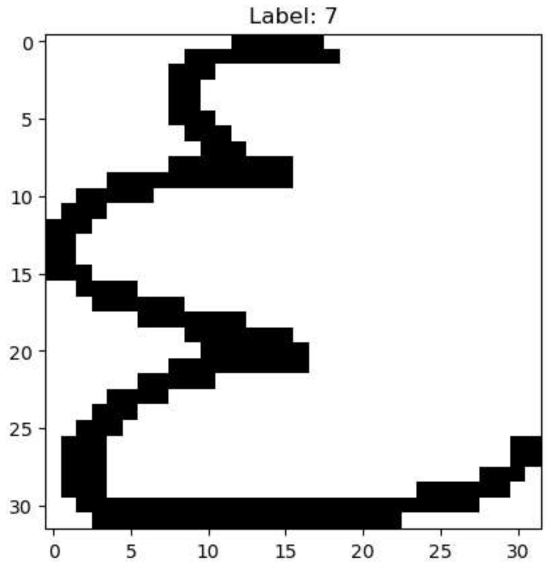
In [13]:
```python
print('x_train',y_train,x_test,y_test)
```

...

In [22]:
```python
# test the images are loaded correctly
print(f"Number of images in training set: {len(x_train)}")
print(f"Number of images in test set: {len(x_test)}")
print(f"Shape of first training image: {x_train[0].shape}")
print(f"Label of first training image: {y_train[0]}")
print(f"Label of 130th test image: {y_test[130]}")

# Display example images
plt.figure(figsize=(8, 5))
plt.subplot(1, 2, 1)
plt.imshow(x_train[1], cmap='gray')
plt.title(f"Label: {y_train[1]}")
plt.subplot(1, 2, 2)
plt.imshow(x_train[988], cmap='gray')
plt.title(f"Label: {y_train[972]}")
plt.show()

# Display an image from the test set
plt.figure()
plt.imshow(x_test[120], cmap='gray')
plt.title(f"Label: {y_test[122]}")
plt.show()
```

```
Number of images in training set: 1000
Number of images in test set: 178
Shape of first training image: (32, 32)
Label of first training image: 0
Label of 130th test image: 7
```




Label: 7
0
5
10
15
20
25
30

In [25]:

```python
# 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 [==============================] - 0s 6ms/step - loss: 171.1082 - accuracy: 0.3850 - val_loss: 52.0979 - val_accuracy: 0.5674
Epoch 2/10
32/32 [==============================] - 0s 3ms/step - loss: 26.0582 - accuracy: 0.7840 - val_loss: 25.3502 - val_accuracy: 0.7472
Epoch 3/10
32/32 [==============================] - 0s 2ms/step - loss: 15.5550 - accuracy: 0.8670 - val_loss: 25.0089 - val_accuracy: 0.7921
Epoch 4/10
32/32 [==============================] - 0s 2ms/step - loss: 9.6651 - accuracy: 0.9040 - val_loss: 27.1390 - val_accuracy: 0.7921
Epoch 5/10
32/32 [==============================] - 0s 2ms/step - loss: 8.6695 - accuracy: 0.9100 - val_loss: 17.5808 - val_accuracy: 0.8596
Epoch 6/10
32/32 [==============================] - 0s 2ms/step - loss: 5.5868 - accuracy: 0.9410 - val_loss: 19.8201 - val_accuracy: 0.8483
Epoch 7/10
32/32 [==============================] - 0s 2ms/step - loss: 4.8666 - accuracy: 0.9400 - val_loss: 21.4528 - val_accuracy: 0.8652
Epoch 8/10
32/32 [==============================] - 0s 2ms/step - loss: 3.7175 - accuracy: 0.9590 - val_loss: 28.4628 - val_accuracy: 0.8146
Epoch 9/10
32/32 [==============================] - 0s 3ms/step - loss: 3.1027 - accuracy: 0.9580 - val_loss: 27.6232 - val_accuracy: 0.8315
Epoch 10/10
32/32 [==============================] - 0s 2ms/step - loss: 2.7184 - accuracy: 0.9550 - val_loss: 21.8949 - val_accuracy: 0.8371
```

Out[25]:

```
<keras.callbacks.History at 0x2bbaf69e6a0>
```

In [ ]:

```python

# Observation : we see a better accuracy from the 8nd iteration
# now scale and try to check the accuracy, divide dataset by 255
```

In [26]:

```
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 [==============================] - 0s 5ms/step - loss: 0.7920 - accuracy: 0.8890 - val_loss: 1.1143 - val_accuracy: 0.6966
Epoch 2/10
32/32 [==============================] - 0s 2ms/step - loss: 0.7872 - accuracy: 0.8830 - val_loss: 1.0537 - val_accuracy: 0.7472
Epoch 3/10
32/32 [==============================] - 0s 2ms/step - loss: 0.7436 - accuracy: 0.9230 - val_loss: 1.0052 - val_accuracy: 0.7978
Epoch 4/10
32/32 [==============================] - 0s 3ms/step - loss: 0.7128 - accuracy: 0.9560 - val_loss: 0.9705 - val_accuracy: 0.8427
Epoch 5/10
32/32 [==============================] - 0s 3ms/step - loss: 0.6911 - accuracy: 0.9720 - val_loss: 0.9467 - val_accuracy: 0.8708
Epoch 6/10
32/32 [==============================] - 0s 3ms/step - loss: 0.6750 - accuracy: 0.9840 - val_loss: 0.9288 - val_accuracy: 0.8820
Epoch 7/10
32/32 [==============================] - 0s 3ms/step - loss: 0.6630 - accuracy: 0.9880 - val_loss: 0.9159 - val_accuracy: 0.8876
Epoch 8/10
32/32 [==============================] - 0s 3ms/step - loss: 0.6536 - accuracy: 0.9880 - val_loss: 0.9057 - val_accuracy: 0.8820
Epoch 9/10
32/32 [==============================] - 0s 2ms/step - loss: 0.6457 - accuracy: 0.9900 - val_loss: 0.8970 - val_accuracy: 0.8820
Epoch 10/10
```

In [ ]:

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

In [27]:

```
# evaluate test dataset
model.evaluate(x_test_scaled,y_test)
```

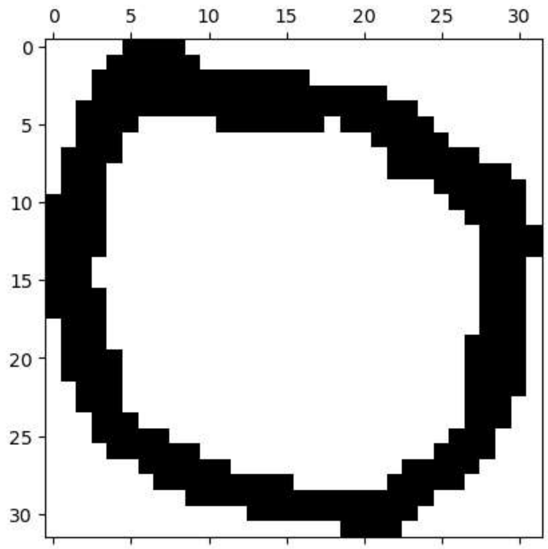
```
6/6 [==============================] - 0s 2ms/step - loss: 0.8896 - accuracy: 0.8933
```

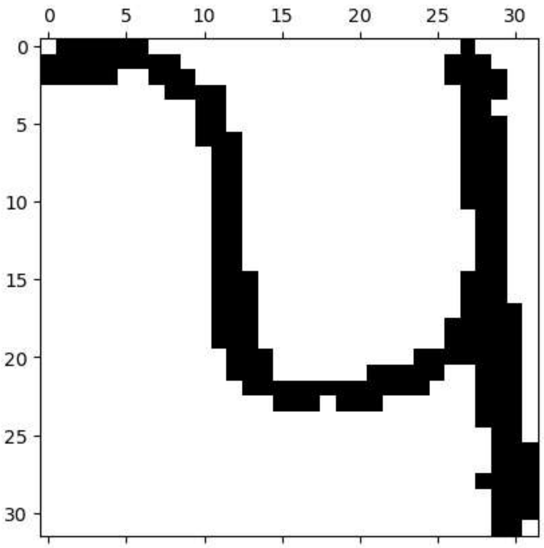
Out[27]:

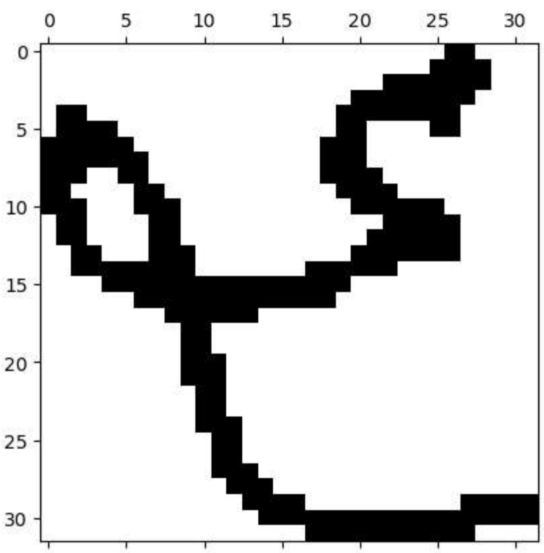
```
[0.8895570635795593, 0.8932584524154663]
```

In [34]:
```python
# Predict the first image
plt.matshow(x_test[0], cmap='gray')
y_predicted = model.predict(x_test_scaled)
print("Prediction for the first image:", np.argmax(y_predicted[0]))

# Test some more values
plt.matshow(x_test[88], cmap='gray')
print("Prediction for image 78:", np.argmax(y_predicted[78]))

plt.matshow(x_test[177], cmap='gray')
print("Prediction for image 144:", np.argmax(y_predicted[144]))
```

```
6/6 [==============================] - 0s 3ms/step
Prediction for the first image: 0
Prediction for image 78: 4
Prediction for image 144: 8
```




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 [35]:

```python
# 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
```

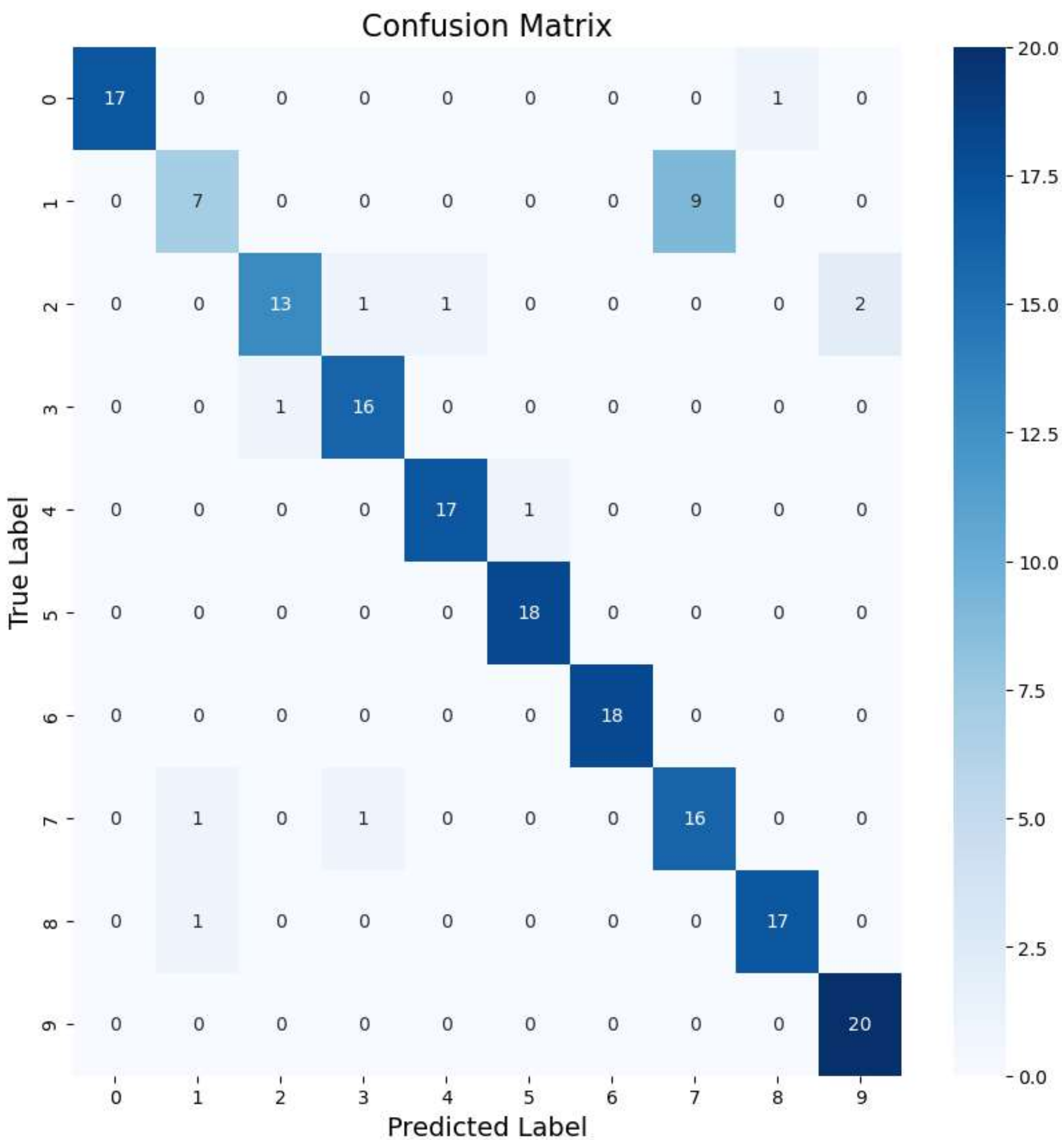
```
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 7, 7, 7, 1, 1, 1, 1, 1, 1, 1, 7, 7, 7, 7, 7, 7, 2, 2, 3, 2, 2, 2, 2, 2, 2, 2, 2, 2, 9, 4, 2, 2, 9, 3, 3, 3, 3, 3, 3, 3
3, 3, 3, 2, 3, 3, 3, 3, 3, 3, 4, 5, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5,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

Out[35]:

```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[17,  0,  0,  0,  0,  0,  0,  0,  1,  0],
       [ 0,  7,  0,  0,  0,  0,  0,  9,  0,  0],
       [ 0,  0, 13,  1,  1,  0,  0,  0,  0,  2],
       [ 0,  0,  1, 16,  0,  0,  0,  0,  0,  0],
       [ 0,  0,  0,  0, 17,  1,  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,  1,  0,  1,  0,  0,  0, 16,  0,  0],
       [ 0,  1,  0,  0,  0,  0,  0,  0, 17,  0],
       [ 0,  0,  0,  0,  0,  0,  0,  0,  0, 20]])>
```

In [40]:

```
import seaborn as sns

plt.figure(figsize=(10, 10))
sns.heatmap(conf_mat, annot=True, fmt='d', cmap='Blues')
plt.xlabel('Predicted Label', fontsize=14)
plt.ylabel('True Label', fontsize=14)
plt.title('Confusion Matrix', fontsize=16)
plt.show()
plt.show()
```



In [ ]:

```
# 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 [41]:

```

# 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 [==============================] - 3s 54ms/step - loss: 1.2606 - accuracy: 0.7080 - val_loss: 0.4655 - val_accuracy: 0.8427
Epoch 2/10
32/32 [==============================] - 1s 35ms/step - loss: 0.1965 - accuracy: 0.9410 - val_loss: 0.2809 - val_accuracy: 0.9213
Epoch 3/10
32/32 [==============================] - 1s 35ms/step - loss: 0.1299 - accuracy: 0.9670 - val_loss: 0.3043 - val_accuracy: 0.9045
Epoch 4/10
32/32 [==============================] - 1s 36ms/step - loss: 0.0722 - accuracy: 0.9770 - val_loss: 0.3462 - val_accuracy: 0.8989
Epoch 5/10
32/32 [==============================] - 1s 34ms/step - loss: 0.0525 - accuracy: 0.9880 - val_loss: 0.2107 - val_accuracy: 0.9438
Epoch 6/10
32/32 [==============================] - 1s 33ms/step - loss: 0.0499 - accuracy: 0.9890 - val_loss: 0.2080 - val_accuracy: 0.9438
Epoch 7/10
32/32 [==============================] - 1s 35ms/step - loss: 0.0208 - accuracy: 0.9970 - val_loss: 0.1837 - val_accuracy: 0.9494
Epoch 8/10
32/32 [==============================] - 1s 32ms/step - loss: 0.0150 - accuracy: 1.0000 - val_loss: 0.1972 - val_accuracy: 0.9438
Epoch 9/10
32/32 [==============================] - 1s 32ms/step - loss: 0.0108 - accuracy: 1.0000 - val_loss: 0.1864 - val_accuracy: 0.9494
Epoch 10/10
32/32 [==============================] - 1s 37ms/step - loss: 0.0098 - accuracy: 1.0000 - val_loss: 0.1871 - val_accuracy: 0.9551
```

In [42]:

```
# 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 9ms/step - loss: 0.1871 - accuracy: 0.9551
```

Out[42]:

```
[0.18714649975299835, 0.9550561904907227]
```

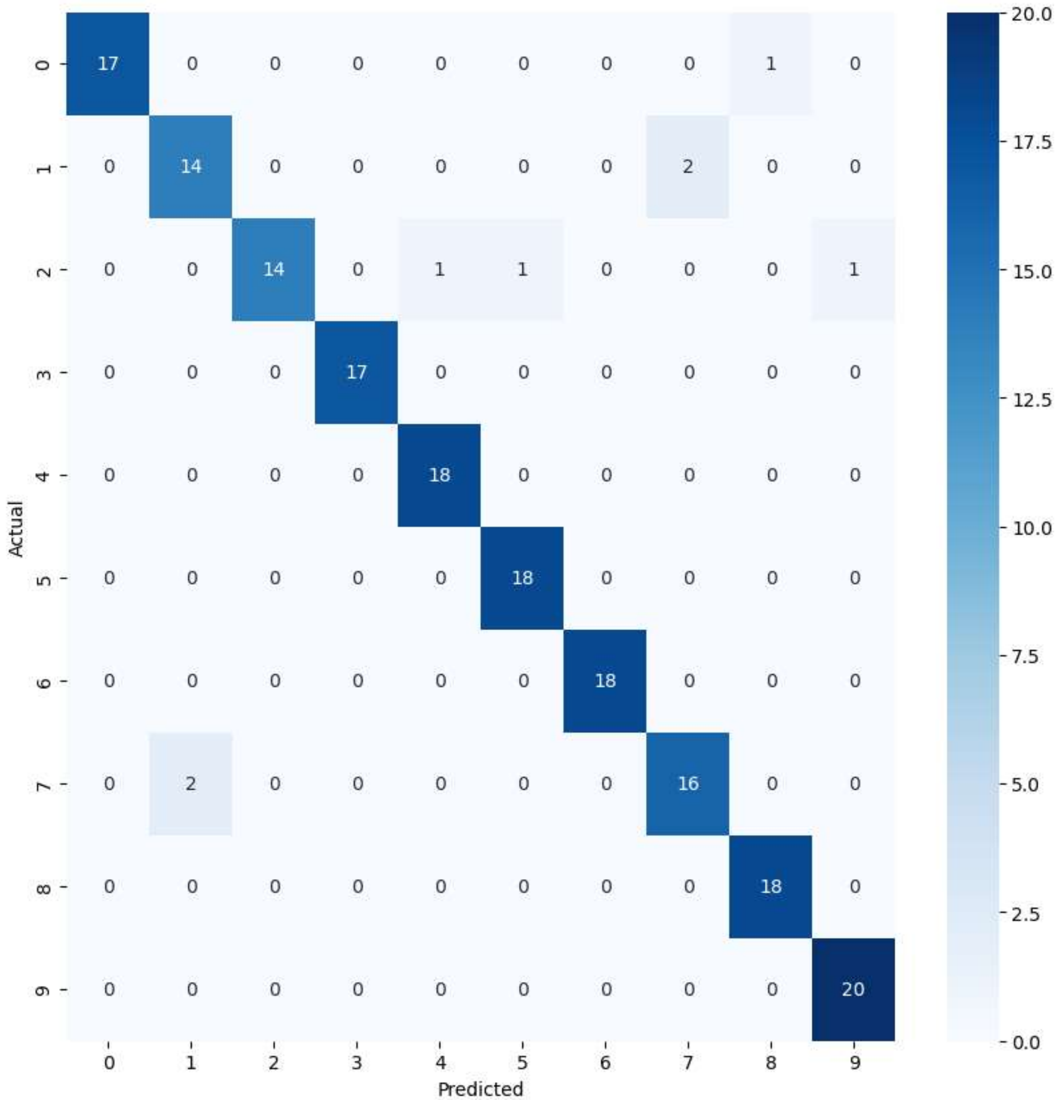
In [43]:
```python
# Earlier we got 0.9213483333587646 now we got 0.9606741666793823 accuracy
# redo the confusion matrix
# build confusion matrix to see how our prediction looks like
# convert to concrete values
y_predicted = model2.predict(x_test_scaled)
y_predicted[0]
y_predicted_labels=[np.argmax(i) 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 11ms/step
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 8, 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[43]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[17,  0,  0,  0,  0,  0,  0,  0,  1,  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 [45]:
```
plt.figure(figsize = (10,10))
sn.heatmap(conf_mat,annot=True,fmt='d',cmap='Blues')
plt.xlabel('Predicted')
plt.ylabel('Actual')
```

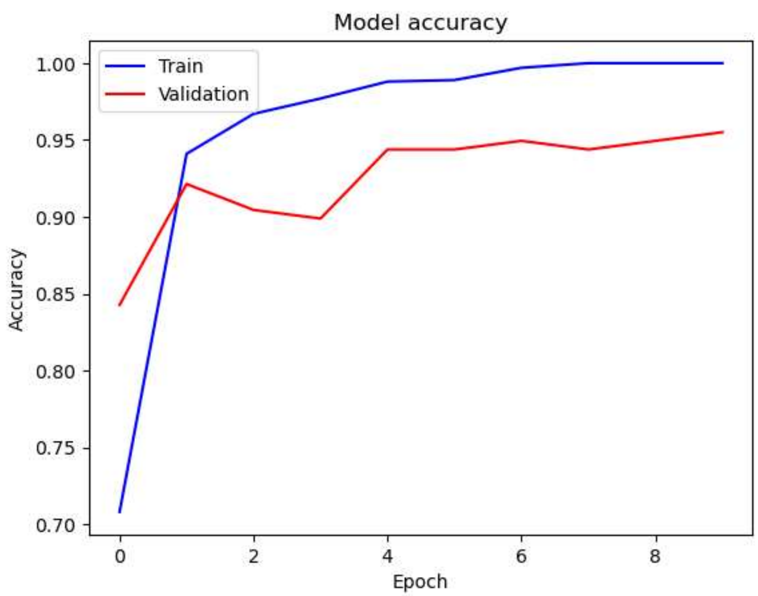
Out[45]: `Text(95.72222222222221, 0.5, 'Actual')`



In [ ]:
```
# Observatoin : we see in the updated model, there are less number of errors,
```

In [47]:
```
# 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'], color='blue')
plt.plot(history.history['val_accuracy'], color='red')
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
```

```
6/6 [==============================] - 0s 7ms/step - loss: 18.2747 - accuracy: 0.8876
Test accuracy: 0.8876404762268066
```



In [ ]:
```

```