DigitsRecognition

July 29, 2024

[2]:
```
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
import numpy as np
```

0.1 Importing Data

[3]:
```
(x_train, y_train), (x_test, y_test) = keras.datasets.mnist.load_data()
```

[4]:
```
len(x_train)
```

[4]:
```
60000
```

[5]:
```
len(x_test)
```

[5]:
```
10000
```

[6]:
```
x_train[0].shape
```

[6]:
```
(28, 28)
```

[7]:
```
x_train[0]
```

[7]:
```
array([[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
       [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
          0,   0],
```

```
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   3,
  18,  18,  18, 126, 136, 175,  26, 166, 255, 247, 127,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,  30,  36,  94, 154, 170,
 253, 253, 253, 253, 253, 225, 172, 253, 242, 195,  64,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,  49, 238, 253, 253, 253, 253,
 253, 253, 253, 253, 251,  93,  82,  82,  56,  39,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,  18, 219, 253, 253, 253, 253,
 253, 198, 182, 247, 241,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,  80, 156, 107, 253, 253,
 205,  11,   0,  43, 154,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,  14,   1, 154, 253,
  90,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0, 139, 253,
 190,   2,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  11, 190,
 253,  70,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  35,
 241, 225, 160, 108,   1,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
  81, 240, 253, 253, 119,  25,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,  45, 186, 253, 253, 150,  27,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,  16,  93, 252, 253, 187,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0, 249, 253, 249,  64,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,  46, 130, 183, 253, 253, 207,   2,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  39,
 148, 229, 253, 253, 253, 250, 182,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  24, 114, 221,
 253, 253, 253, 253, 201,  78,   0,   0,   0,   0,   0,   0,   0,
```

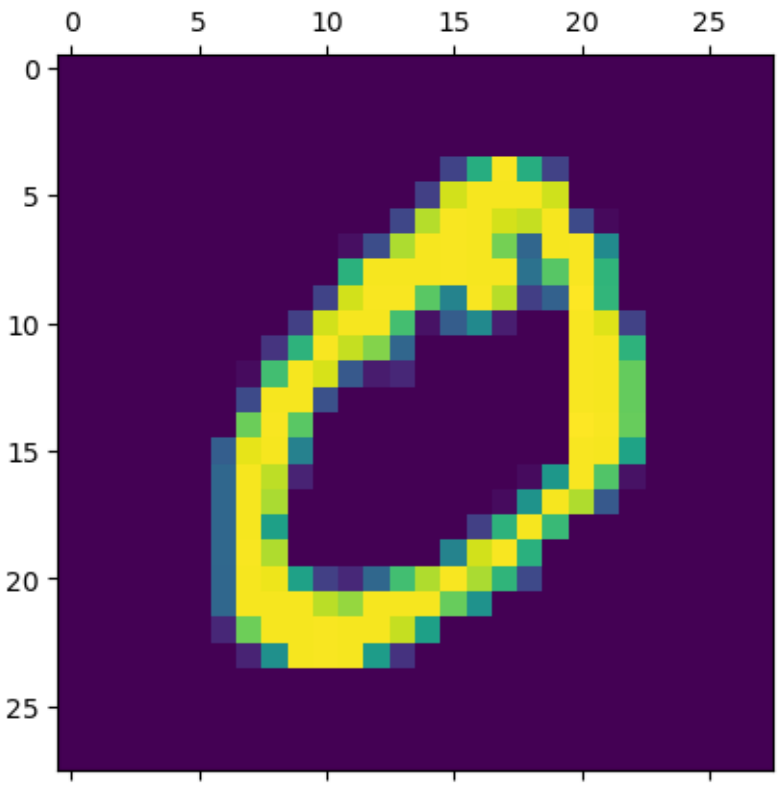
```
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,  23,  66, 213, 253, 253,
 253, 253, 198,  81,   2,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,  18, 171, 219, 253, 253, 253, 253,
 195,  80,   9,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,  55, 172, 226, 253, 253, 253, 253, 244, 133,
  11,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0, 136, 253, 253, 253, 212, 135, 132,  16,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0]], dtype=uint8)
```

[8]:
```
y_train[0]
```

[8]:
```
5
```

[9]:
```
plt.matshow(x_train[1])
```

[9]:
```
<matplotlib.image.AxesImage at 0x20931358070>
```



[10]:
```
y_train[1]
```

[10]:
```
0
```

[11]:
```
x_train.shape
```

[11]:
```
(60000, 28, 28)
```

[12]:
```
x_train = x_train / 255
x_test = x_test / 255
```

[13]:
```
x_train[0]
```

[13]:
```
array([[0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.01176471, 0.07058824, 0.07058824,
 0.07058824, 0.49411765, 0.53333333, 0.68627451, 0.10196078,
 0.65098039, 1.        , 0.96862745, 0.49803922, 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.11764706, 0.14117647,
 0.36862745, 0.60392157, 0.66666667, 0.99215686, 0.99215686,
 0.99215686, 0.99215686, 0.99215686, 0.88235294, 0.6745098 ,
 0.99215686, 0.94901961, 0.76470588, 0.25098039, 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.19215686, 0.93333333, 0.99215686,
 0.99215686, 0.99215686, 0.99215686, 0.99215686, 0.99215686,
 0.99215686, 0.99215686, 0.98431373, 0.36470588, 0.32156863,
 0.32156863, 0.21960784, 0.15294118, 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.07058824, 0.85882353, 0.99215686,
 0.99215686, 0.99215686, 0.99215686, 0.99215686, 0.77647059,
 0.71372549, 0.96862745, 0.94509804, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.31372549, 0.61176471,
```

```
 0.41960784, 0.99215686, 0.99215686, 0.80392157, 0.04313725,
 0.        , 0.16862745, 0.60392157, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.05490196,
 0.00392157, 0.60392157, 0.99215686, 0.35294118, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.54509804, 0.99215686, 0.74509804, 0.00784314,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.04313725, 0.74509804, 0.99215686, 0.2745098 ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.1372549 , 0.94509804, 0.88235294,
 0.62745098, 0.42352941, 0.00392157, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.31764706, 0.94117647,
 0.99215686, 0.99215686, 0.46666667, 0.09803922, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.17647059,
 0.72941176, 0.99215686, 0.99215686, 0.58823529, 0.10588235,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.0627451 , 0.36470588, 0.98823529, 0.99215686, 0.73333333,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
```

```
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.97647059, 0.99215686, 0.97647059,
 0.25098039, 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.18039216,
 0.50980392, 0.71764706, 0.99215686, 0.99215686, 0.81176471,
 0.00784314, 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.15294118, 0.58039216, 0.89803922,
 0.99215686, 0.99215686, 0.99215686, 0.98039216, 0.71372549,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.09411765, 0.44705882, 0.86666667, 0.99215686, 0.99215686,
 0.99215686, 0.99215686, 0.78823529, 0.30588235, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.09019608, 0.25882353,
 0.83529412, 0.99215686, 0.99215686, 0.99215686, 0.99215686,
 0.77647059, 0.31764706, 0.00784314, 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.07058824, 0.67058824, 0.85882353, 0.99215686,
 0.99215686, 0.99215686, 0.99215686, 0.76470588, 0.31372549,
 0.03529412, 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.21568627,
 0.6745098 , 0.88627451, 0.99215686, 0.99215686, 0.99215686,
 0.99215686, 0.95686275, 0.52156863, 0.04313725, 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.53333333,
 0.99215686, 0.99215686, 0.99215686, 0.83137255, 0.52941176,
 0.51764706, 0.0627451 , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
```

```
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.       ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.       ],
       [0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.        , 0.        , 0.        ,
        0.        , 0.        , 0.       ]])
```

[14]:
```
x_train_flattened = x_train.reshape(len(x_train), 28*28)
x_test_flattened = x_test.reshape(len(x_test), 28*28)
x_test_flattened.shape
```

[14]:
```
(10000, 784)
```

0.2 Building and Testing model

[15]:
```
model = keras.Sequential([
    keras.layers.Dense(10, input_shape=(784,),activation='sigmoid')
])

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

model.fit(x_train_flattened, y_train, epochs=5)
```

```
Epoch 1/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.4682 -
accuracy: 0.8782
Epoch 2/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.3040 -
accuracy: 0.9147
Epoch 3/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2834 -
accuracy: 0.9206
```

```
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2735 -
accuracy: 0.9233
Epoch 5/5
1875/1875 [==============================] - 2s 979us/step - loss: 0.2669 -
accuracy: 0.9253
```

[15]: `<keras.callbacks.History at 0x209344bf0a0>`

[16]:
```
model.evaluate(x_test_flattened, y_test)
```

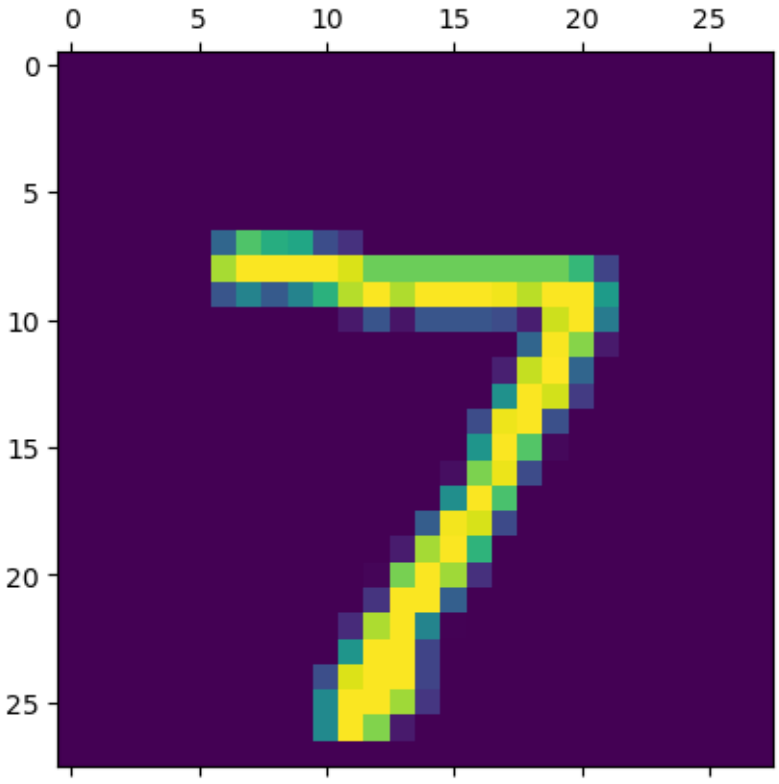
```
313/313 [==============================] - 1s 2ms/step - loss: 0.2696 -
accuracy: 0.9252
```

[16]: `[0.269618421792984, 0.9251999855041504]`

0.3 Testing

[17]:
```
plt.matshow(x_test[0])
```

[17]: `<matplotlib.image.AxesImage at 0x2095e2e43a0>`



[18]:
```
y_hat = model.predict(x_test_flattened)
```

```
313/313 [==============================] - 0s 859us/step
```

[19]:
```
y_hat[0]
```

[19]:
```
array([2.1209173e-02, 4.3643428e-07, 4.9341932e-02, 9.3399256e-01,
       1.8216661e-03, 1.1273272e-01, 1.2217317e-06, 9.9968565e-01,
       9.4176687e-02, 7.3584163e-01], dtype=float32)
```

0.4 Result

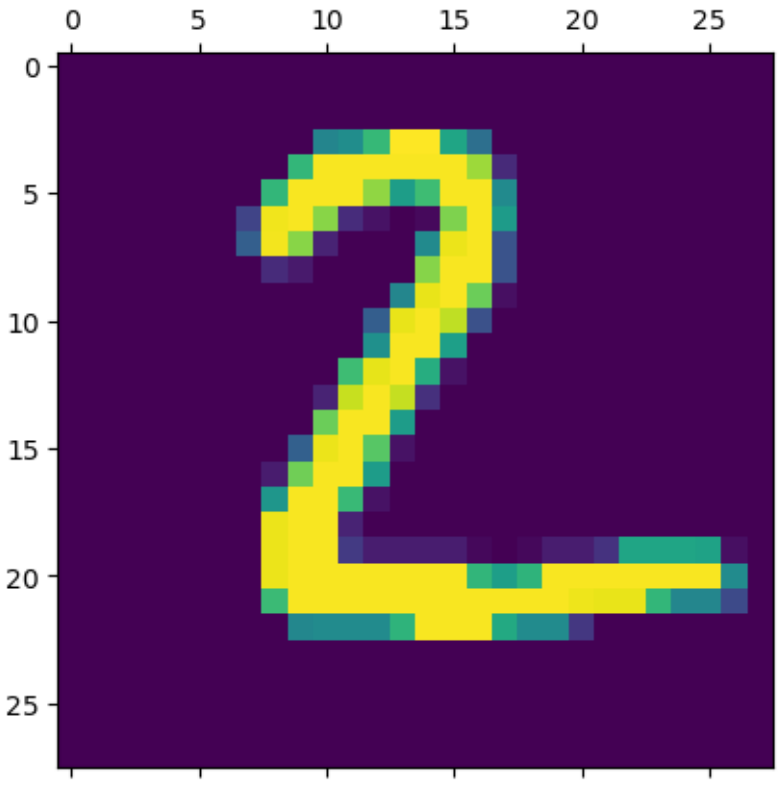
[20]:
```
np.argmax(y_hat[0])
```

[20]:
```
7
```

0.5 One more testing

[21]:
```
plt.matshow(x_test[1])
```

[21]:
```
<matplotlib.image.AxesImage at 0x2095e329cf0>
```



[22]:
```
np.argmax(y_hat[1])
```

[22]:
```
2
```

[23]:
```
y_hat_labels = [np.argmax(i) for i in y_hat]
y_hat_labels[:3]
```

[23]:
```
[7, 2, 1]
```

0.6 Improving the model's accuracy

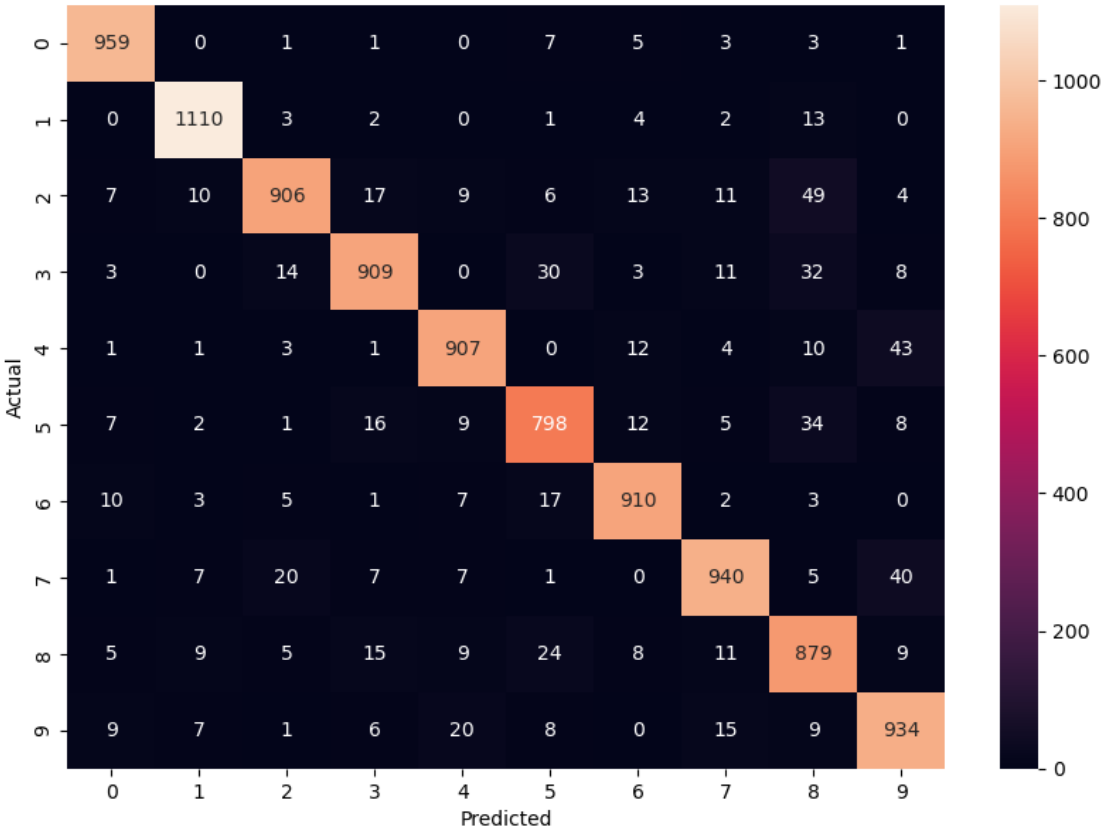
[24]:
```
cm = tf.math.confusion_matrix(labels=y_test, predictions=y_hat_labels)
cm
```

[24]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 959,    0,    1,    1,    0,    7,    5,    3,    3,    1],
       [   0, 1110,    3,    2,    0,    1,    4,    2,   13,    0],
       [   7,   10,  906,   17,    9,    6,   13,   11,   49,    4],
       [   3,    0,   14,  909,    0,   30,    3,   11,   32,    8],
       [   1,    1,    3,    1,  907,    0,   12,    4,   10,   43],
       [   7,    2,    1,   16,    9,  798,   12,    5,   34,    8],
       [  10,    3,    5,    1,    7,   17,  910,    2,    3,    0],
       [   1,    7,   20,    7,    7,    1,    0,  940,    5,   40],
       [   5,    9,    5,   15,    9,   24,    8,   11,  879,    9],
       [   9,    7,    1,    6,   20,    8,    0,   15,    9,  934]])>
```

[25]:
```
cm = tf.math.confusion_matrix(labels=y_test, predictions=y_hat_labels)
cm
```

[25]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 959,    0,    1,    1,    0,    7,    5,    3,    3,    1],
       [   0, 1110,    3,    2,    0,    1,    4,    2,   13,    0],
       [   7,   10,  906,   17,    9,    6,   13,   11,   49,    4],
       [   3,    0,   14,  909,    0,   30,    3,   11,   32,    8],
       [   1,    1,    3,    1,  907,    0,   12,    4,   10,   43],
       [   7,    2,    1,   16,    9,  798,   12,    5,   34,    8],
       [  10,    3,    5,    1,    7,   17,  910,    2,    3,    0],
       [   1,    7,   20,    7,    7,    1,    0,  940,    5,   40],
       [   5,    9,    5,   15,    9,   24,    8,   11,  879,    9],
       [   9,    7,    1,    6,   20,    8,    0,   15,    9,  934]])>
```

[26]:
```
import seaborn as sns
plt.figure(figsize= (10,7))
sns.heatmap(cm, annot=True, fmt='g')
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.show()
```



[27]:
```
model = keras.Sequential([
    keras.layers.Dense(200, input_shape=(784,),activation='relu'),
    keras.layers.Dense(10,activation='sigmoid')

])

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

model.fit(x_train_flattened, y_train, epochs=5)
```

```
Epoch 1/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.2384 -
accuracy: 0.9317
Epoch 2/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.1003 -
accuracy: 0.9702
Epoch 3/5
```

```
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0661 -
accuracy: 0.9802
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0477 -
accuracy: 0.9847
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0358 -
accuracy: 0.9885
```

[27]:
```
<keras.callbacks.History at 0x2095f237340>
```

[28]:
```
model.evaluate(x_test_flattened, y_test)
```

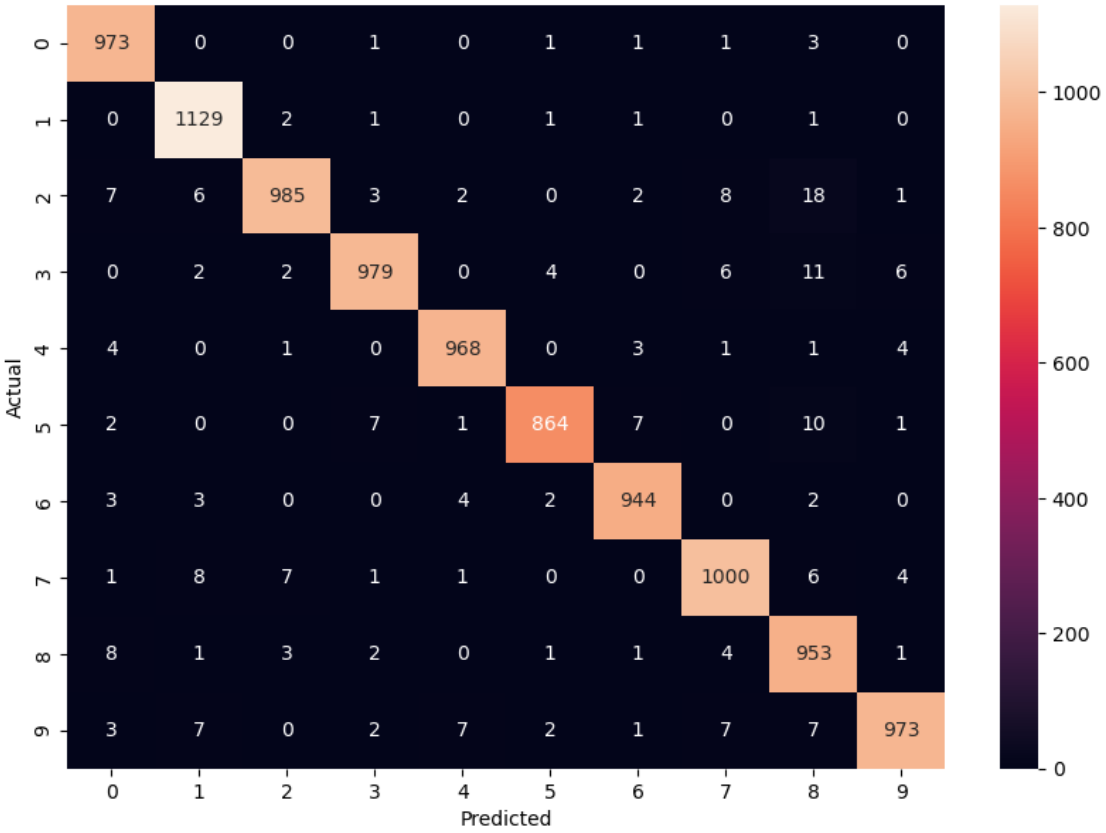
```
313/313 [==============================] - 1s 2ms/step - loss: 0.0720 -
accuracy: 0.9768
```

[28]:
```
[0.07204367220401764, 0.9768000245094299]
```

[29]:
```
y_hat = model.predict(x_test_flattened)
y_hat_labels = [np.argmax(i) for i in y_hat]
cm = tf.math.confusion_matrix(labels=y_test, predictions=y_hat_labels)


plt.figure(figsize= (10,7))
sns.heatmap(cm, annot=True, fmt='g')
plt.xlabel('Predicted')
plt.ylabel('Actual')
plt.show()
```

```
313/313 [==============================] - 0s 803us/step
```



[30]:
```
model = keras.Sequential([
    keras.layers.Flatten(input_shape=(28,28)),
    keras.layers.Dense(200,activation='relu'),
    keras.layers.Dense(10,activation='relu')
])

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

model.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1875/1875 [==============================] - 3s 1ms/step - loss: 2.2614 -
accuracy: 0.1379
Epoch 2/5
1875/1875 [==============================] - 2s 1ms/step - loss: 2.2263 -
accuracy: 0.1369
Epoch 3/5
```

```
1875/1875 [==============================] - 2s 1ms/step - loss: 2.2380 -
accuracy: 0.1271
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 2.2510 -
accuracy: 0.1212
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 2.2667 -
accuracy: 0.1143
```

[30]: `<keras.callbacks.History at 0x2095256af50>`

[31]:
```
model = keras.Sequential([
    keras.layers.Flatten(input_shape=(28,28)),
    keras.layers.Dense(200,activation='relu'),
    keras.layers.Dense(10,activation='sigmoid')
])

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

model.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.2305 -
accuracy: 0.9341
Epoch 2/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0987 -
accuracy: 0.9705
Epoch 3/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0650 -
accuracy: 0.9804
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0486 -
accuracy: 0.9848
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0358 -
accuracy: 0.9888
```

[31]: `<keras.callbacks.History at 0x20952531930>`

model = keras.Sequential([keras.layers.Flatten(input_shape=(28,28)), keras.layers.Dense(200,activation='relu'), keras.layers.Dense(10,activation='sigmoid')])

model.compile(optimizer='rmsprop', loss='sparse_categorical_crossentropy', metrics=['accuracy'])

model.fit(x_train, y_train, epochs=5)

```
model = keras.Sequential([ keras.layers.Flatten(input_shape=(28,28)), keras.layers.Dense(200,activation='relu'), keras.layers.Dense(10,activation='sigmoid')])

model.compile( optimizer='adagrad', loss='binary_crossentropy', metrics=['accuracy'] )

model.fit(x_train, y_train, epochs=5)
```

[ ]: