In [3]:
```
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
import matplotlib.pyplot as plt
import numpy as np
%matplotlib inline
```

```
WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\losses.py:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecated. Please use tf.compat.v1.losses.sparse_softmax_cross_entropy instead.
```

In [4]:
```
(X_train,y_train),(X_test,y_test)=keras.datasets.mnist.load_data()
```

In [3]:
```
len(X_train)
```

Out[3]:
```
60000
```

In [4]:
```
len(X_test)
```

Out[4]:
```
10000
```

In [5]:
```
X_train.shape
```

Out[5]:
```
(60000, 28, 28)
```

In [6]:
```
y_train.shape
```

Out[6]:
```
(60000,)
```

In [7]:
```
X_train[0].shape
```

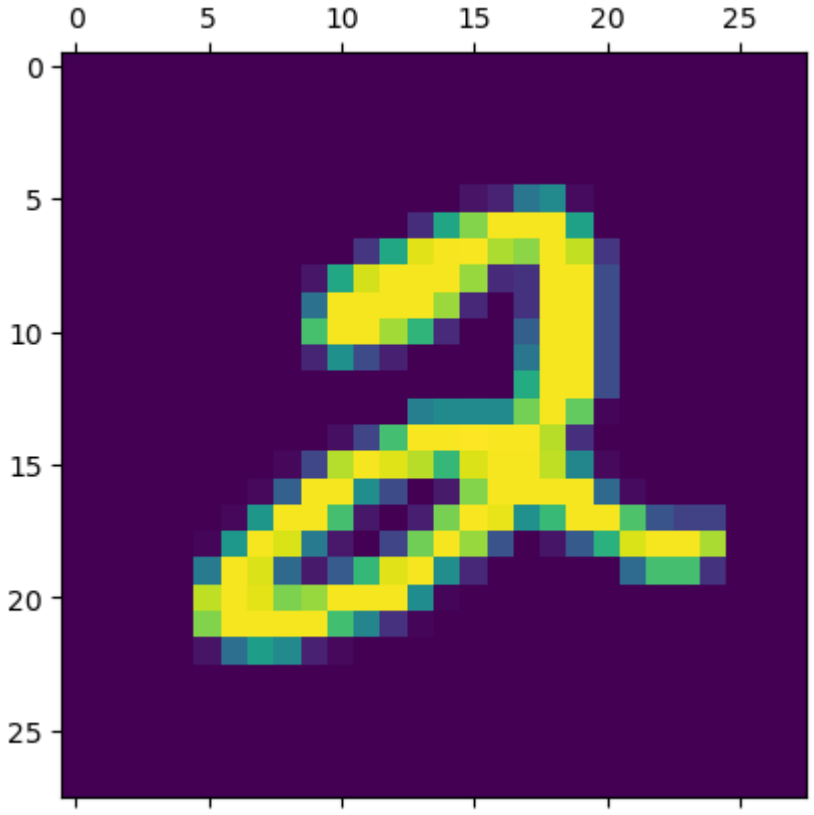
Out[7]:
```
(28, 28)
```

In [8]:
```
X_train[0]
```

```
Out[8]: 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)
```

In [5]:
```
plt.matshow(X_train[5]);
```



In [6]:
```
y_train[5]
```

Out[6]:
```
2
```

Scaling

In [11]:
```
X_train=X_train/255
X_test=X_test/255
```

In [12]:
```
X_train[0]
```

```
Out[12]: 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.        ]])
```

Model Building

In [13]:

```
model=keras.models.Sequential([
    #CNN
    layers.Conv2D(filters=32,kernel_size=(3,3),activation='relu',input_shape=(28,28,1)),
```

```
    layers.MaxPooling2D(2,2),
    layers.Conv2D(filters=32,kernel_size=(3,3),activation='relu'),
    layers.MaxPooling2D(2,2),

    # Dense
    layers.Flatten(),
    layers.Dense(64,activation='relu'),
    layers.Dense(10,activation='softmax')
])


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


model.fit(X_train,y_train,epochs=11)
```

```
WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\backend.py:873: The name tf.get_default_graph is depre
cated. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\layers\pooling\max_pooling2d.py:161: The name tf.nn.ma
x_pool is deprecated. Please use tf.nn.max_pool2d instead.

WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\optimizers\__init__.py:309: The name tf.train.Optimize
r is deprecated. Please use tf.compat.v1.train.Optimizer instead.

Epoch 1/11
WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\utils\tf_utils.py:492: The name tf.ragged.RaggedTensor
Value is deprecated. Please use tf.compat.v1.ragged.RaggedTensorValue instead.

WARNING:tensorflow:From C:\Users\hp\anaconda3\Lib\site-packages\keras\src\engine\base_layer_utils.py:384: The name tf.executing_
eagerly_outside_functions is deprecated. Please use tf.compat.v1.executing_eagerly_outside_functions instead.

1875/1875 [==============================] - 26s 13ms/step - loss: 0.1565 - accuracy: 0.9528
Epoch 2/11
1875/1875 [==============================] - 22s 12ms/step - loss: 0.0533 - accuracy: 0.9838
Epoch 3/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0372 - accuracy: 0.9886
Epoch 4/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0295 - accuracy: 0.9906
Epoch 5/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0228 - accuracy: 0.9927
Epoch 6/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0187 - accuracy: 0.9940
Epoch 7/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0153 - accuracy: 0.9950
Epoch 8/11
1875/1875 [==============================] - 22s 12ms/step - loss: 0.0125 - accuracy: 0.9959
Epoch 9/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0095 - accuracy: 0.9967
Epoch 10/11
1875/1875 [==============================] - 23s 12ms/step - loss: 0.0081 - accuracy: 0.9976
Epoch 11/11
1875/1875 [==============================] - 22s 12ms/step - loss: 0.0081 - accuracy: 0.9973
```

Out[13]: `<keras.src.callbacks.History at 0x15ee065d850>`

Evaluate the Model

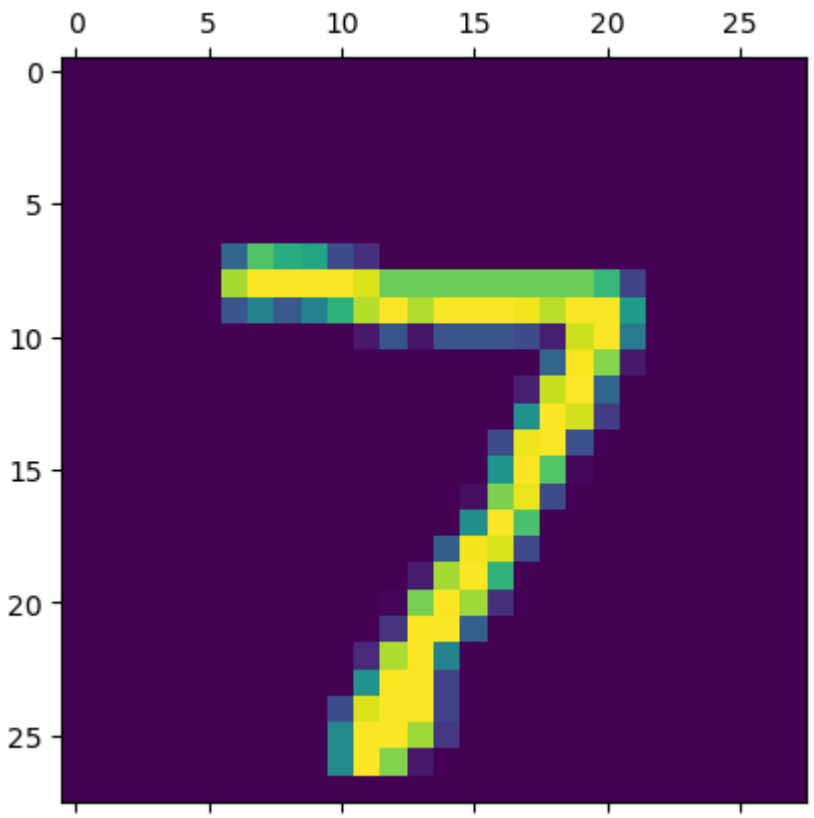
In [14]:
```
model.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 2s 6ms/step - loss: 0.0378 - accuracy: 0.9909
[0.037803489714860916, 0.9908999800682068]
```

Out[14]:

In [15]:
```
plt.matshow(X_test[])
```

Out[15]:
```
<matplotlib.image.AxesImage at 0x15edcc8c450>
```



In [16]:
```
y_predicted=model.predict(X_test)
```

```
313/313 [==============================] - 2s 5ms/step
```

In [17]:
```
y_predicted[0]
```

Out[17]:
```
array([8.45239937e-12, 3.59989538e-11, 2.34271214e-10, 1.80230864e-09,
       1.85522101e-11, 1.37124242e-12, 1.05921576e-16, 9.99999762e-01,
       1.44784349e-11, 2.87314577e-07], dtype=float32)
```

In [18]:
```
np.argmax(y_predicted[0])
```

Out[18]:
```
7
```

In [19]:
```
y_pred=[np.argmax(i) for i in y_predicted]
```

In [20]:
```
y_pred[:5]
```

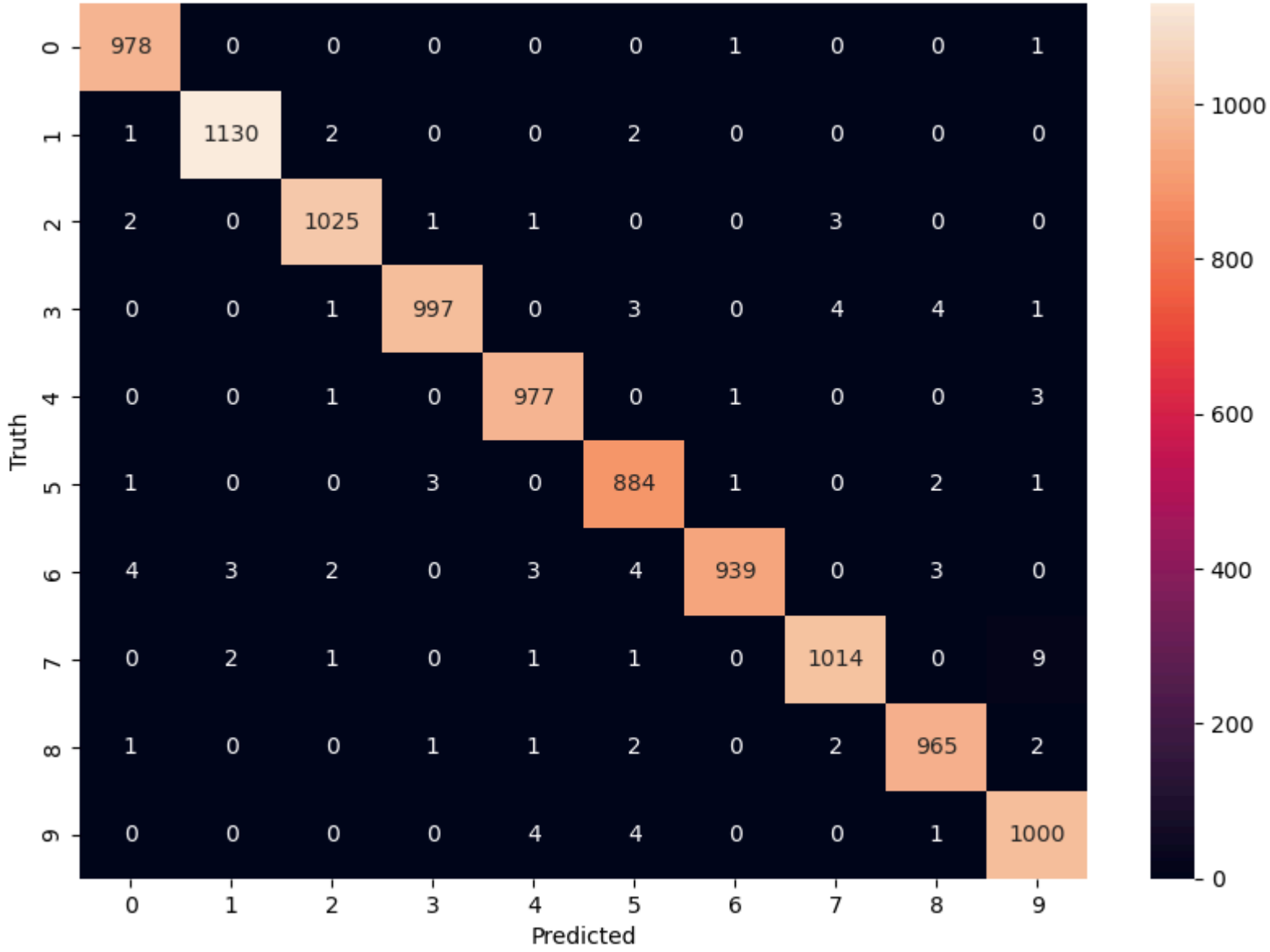
Out[20]:
```
[7, 2, 1, 0, 4]
```

In [21]:
```
cm=tf.math.confusion_matrix(labels=y_test,predictions=y_pred)
cm
```

Out[21]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 978,    0,    0,    0,    0,    0,    1,    0,    0,    1],
       [   1, 1130,    2,    0,    0,    2,    0,    0,    0,    0],
       [   2,    0, 1025,    1,    1,    0,    0,    3,    0,    0],
       [   0,    0,    1,  997,    0,    3,    0,    4,    4,    1],
       [   0,    0,    1,    0,  977,    0,    1,    0,    0,    3],
       [   1,    0,    0,    3,    0,  884,    1,    0,    2,    1],
       [   4,    3,    2,    0,    3,    4,  939,    0,    3,    0],
       [   0,    2,    1,    0,    1,    1,    0, 1014,    0,    9],
       [   1,    0,    0,    1,    1,    2,    0,    2,  965,    2],
       [   0,    0,    0,    0,    4,    4,    0,    0,    1, 1000]])>
```

In [22]:
```
import seaborn as sns
plt.figure(figsize=(10,7))
sns.heatmap(cm,annot=True,fmt='d')
plt.xlabel("Predicted")
plt.ylabel('Truth')
```

Out[22]:
```
Text(95.72222222222221, 0.5, 'Truth')
```


Truth
Predicted
0 978 0 0 0 0 0 1 0 0 1
1 1 1130 2 0 0 2 0 0 0 0
2 2 0 1025 1 1 0 0 3 0 0
3 0 0 1 997 0 3 0 4 4 1
4 0 0 1 0 977 0 1 0 0 3
5 1 0 0 3 0 884 1 0 2 1
6 4 3 2 0 3 4 939 0 3 0
7 0 2 1 0 1 1 0 1014 0 9
8 1 0 0 1 1 2 0 2 965 2
9 0 0 0 0 4 4 0 0 1 1000
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0