In [1]:

```
import tensorflow as tf
from tensorflow import keras
import matplotlib.pyplot as plt
%matplotlib inline
import numpy as np
```

In [2]:

```
(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[0].shape
```

Out[5]:

```
(28, 28)
```

In [6]:

```
X_train[0]
```

Out[6]:

```
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,
```

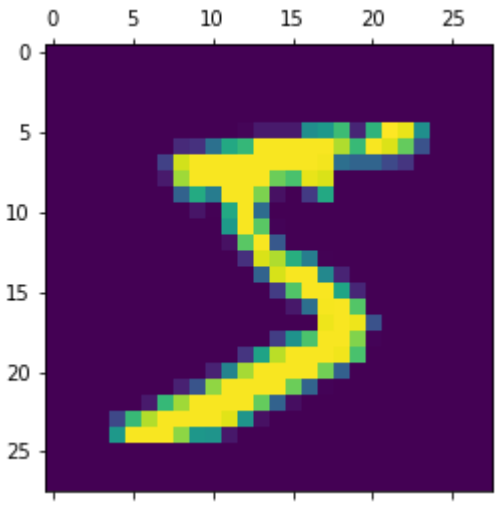
```
       0,   0],
      [  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,  24, 114, 221,
       253, 253, 253, 253, 201,  78,   0,   0,   0,   0,   0,   0,   0,
       0,   0],
      [  0,   0,   0,   0,   0,   0,   0,   0,  23,  66, 213, 253, 253,
       253, 253, 198,  81,   2,   0,   0,   0,   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 [7]:

```
plt.matshow(X_train[0])
```

Out[7]:

```
<matplotlib.image.AxesImage at 0x21d738dc508>
```



In [8]:

```
y_train[2]
```

Out[8]:

```
4
```

In [9]:

```
y_train[:5]
```

Out[9]:

```
array([5, 0, 4, 1, 9], dtype=uint8)
```

In [10]:

```
X_train.shape
```

Out[10]:

```
(60000, 28, 28)
```

In [11]:

```
X_train = X_train / 255
```

In [12]:

```
X_train_flattened = X_train.reshape(len(X_train),28 * 28)
X_train_flattened.shape
```

Out[12]:

```
(60000, 784)
```

In [13]:

```
X_test.shape
```

Out[13]:

```
(10000, 28, 28)
```

In [14]:

```
X_test = X_test / 255
```

In [15]:

```
X_train[0]
```

Out[15]:

```
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.        ]])
```

In [16]:

```
X_test_flattened = X_test.reshape(len(X_test), 28 * 28)
X_test_flattened.shape
```

Out[16]:

```
(10000, 784)
```

In [17]:

```
X_train_flattened[0]
```

Out[17]:

```
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.        ])
```

In [18]:

```
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 = 10)
```

```
Train on 60000 samples
Epoch 1/10
60000/60000 [==============================] - 5s 79us/sample - loss: 0.48
83 - accuracy: 0.8758
Epoch 2/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.30
59 - accuracy: 0.9147
Epoch 3/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.28
54 - accuracy: 0.9213
Epoch 4/10
60000/60000 [==============================] - 4s 72us/sample - loss: 0.27
42 - accuracy: 0.9238
Epoch 5/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.26
79 - accuracy: 0.9262
Epoch 6/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.26
26 - accuracy: 0.9270
Epoch 7/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.25
88 - accuracy: 0.9286
Epoch 8/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.25
51 - accuracy: 0.9300
Epoch 9/10
60000/60000 [==============================] - 4s 71us/sample - loss: 0.25
29 - accuracy: 0.9306
Epoch 10/10
60000/60000 [==============================] - 4s 73us/sample - loss: 0.25
01 - accuracy: 0.9317
```

Out[18]:

```
<tensorflow.python.keras.callbacks.History at 0x21d73379f88>
```

In [19]:

```
model.evaluate(X_test_flattened, y_test)
```

```
10000/10000 [==============================] - 1s 60us/sample - loss: 0.26
22 - accuracy: 0.9286
```

Out[19]:

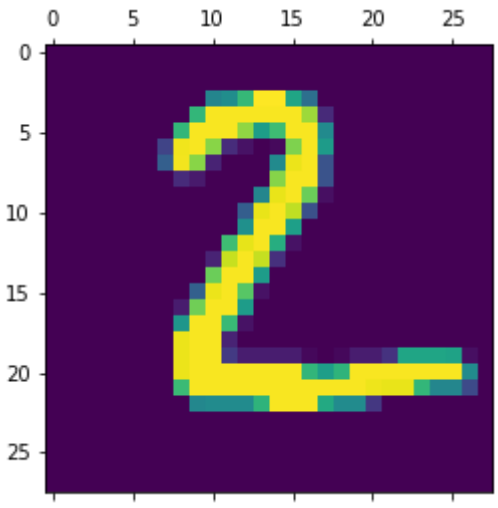
```
[0.2622289415150881, 0.9286]
```

In [20]:

```
plt.matshow(X_test[1])
```

Out[20]:

```
<matplotlib.image.AxesImage at 0x21d7a010788>
```



In [21]:

```
y_predicted = model.predict(X_test_flattened)
y_predicted[1]
```

Out[21]:

```
array([1.7646527e-04, 7.3083322e-07, 8.2608116e-01, 6.3831882e-05,
       1.6834984e-15, 1.9083178e-03, 2.0656353e-03, 8.8439915e-20,
       2.4465753e-05, 2.1175482e-16], dtype=float32)
```

In [22]:

```
np.argmax(y_predicted[1])
```

Out[22]:

```
2
```

In [23]:

```
y_predicted_labels = [np.argmax(i) for i in y_predicted]
y_predicted_labels[:5]
```

Out[23]:

```
[7, 2, 1, 0, 4]
```

In [24]:

```
y_test[:5]
```

Out[24]:

```
array([7, 2, 1, 0, 4], dtype=uint8)
```

In [25]:

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

Out[25]:

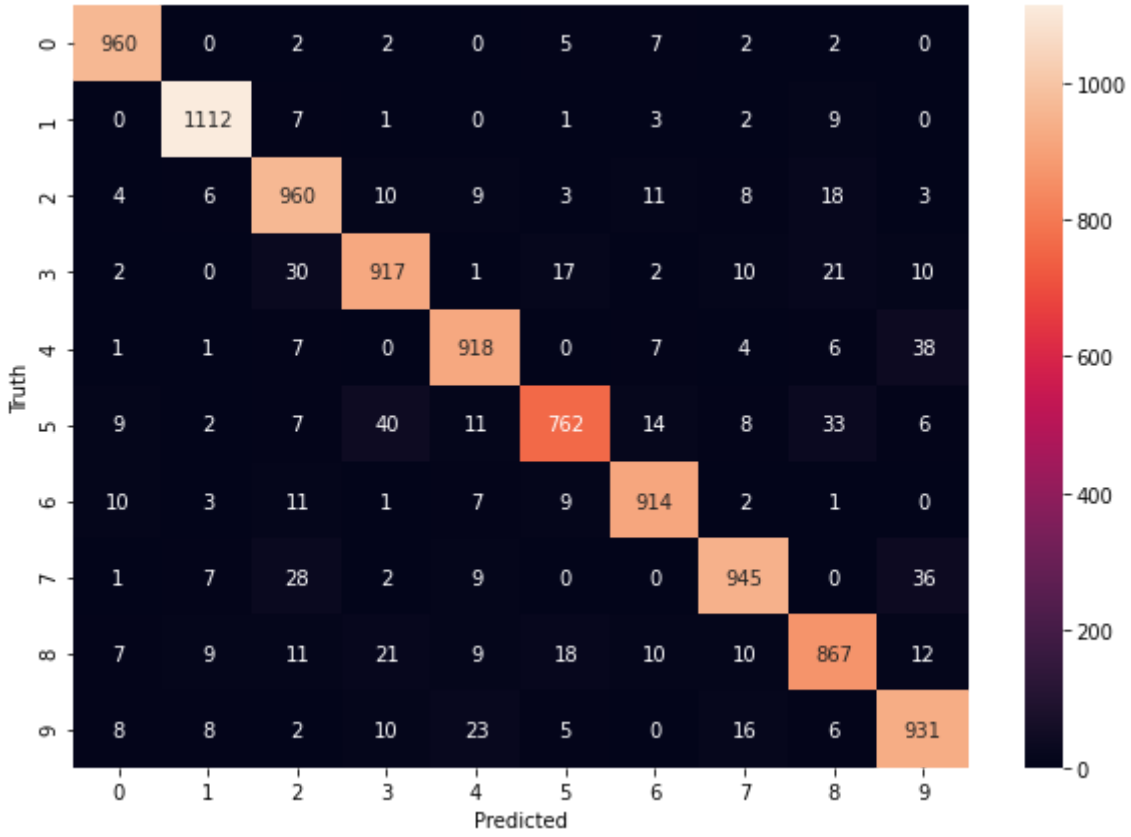
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 960,    0,    2,    2,    0,    5,    7,    2,    2,    0],
       [   0, 1112,    7,    1,    0,    1,    3,    2,    9,    0],
       [   4,    6,  960,   10,    9,    3,   11,    8,   18,    3],
       [   2,    0,   30,  917,    1,   17,    2,   10,   21,   10],
       [   1,    1,    7,    0,  918,    0,    7,    4,    6,   38],
       [   9,    2,    7,   40,   11,  762,   14,    8,   33,    6],
       [  10,    3,   11,    1,    7,    9,  914,    2,    1,    0],
       [   1,    7,   28,    2,    9,    0,    0,  945,    0,   36],
       [   7,    9,   11,   21,    9,   18,   10,   10,  867,   12],
       [   8,    8,    2,   10,   23,    5,    0,   16,    6,  931]])>
```

In [26]:

```
import seaborn as sn
plt.figure(figsize = (10, 7))
sn.heatmap(cm, annot = True, fmt = 'd')
plt.xlabel('Predicted')
plt.ylabel('Truth')
```

Out[26]:

```
Text(69.0, 0.5, 'Truth')
```



In [27]:

```
model = keras.Sequential([
    keras.layers.Dense(100, 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)
```

```
Train on 60000 samples
Epoch 1/5
60000/60000 [==============================] - 6s 97us/sample - loss: 0.29
28 - accuracy: 0.9178
Epoch 2/5
60000/60000 [==============================] - 5s 89us/sample - loss: 0.13
88 - accuracy: 0.9587
Epoch 3/5
60000/60000 [==============================] - 5s 90us/sample - loss: 0.09
83 - accuracy: 0.9704
Epoch 4/5
60000/60000 [==============================] - 5s 91us/sample - loss: 0.07
65 - accuracy: 0.9770
Epoch 5/5
60000/60000 [==============================] - 5s 89us/sample - loss: 0.06
19 - accuracy: 0.9813
```

Out[27]:

```
<tensorflow.python.keras.callbacks.History at 0x21d7bd3dc48>
```

In [28]:

```
model = keras.Sequential([
    keras.layers.Dense(100, 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 = 10)
```

```
Train on 60000 samples
Epoch 1/10
60000/60000 [==============================] - 6s 97us/sample - loss: 0.28
91 - accuracy: 0.9204
Epoch 2/10
60000/60000 [==============================] - 5s 88us/sample - loss: 0.13
07 - accuracy: 0.9621
Epoch 3/10
60000/60000 [==============================] - 5s 87us/sample - loss: 0.09
29 - accuracy: 0.9727
Epoch 4/10
60000/60000 [==============================] - 5s 87us/sample - loss: 0.07
28 - accuracy: 0.9782
Epoch 5/10
60000/60000 [==============================] - 5s 90us/sample - loss: 0.05
99 - accuracy: 0.9817
Epoch 6/10
60000/60000 [==============================] - 5s 88us/sample - loss: 0.04
92 - accuracy: 0.9855
Epoch 7/10
60000/60000 [==============================] - 5s 89us/sample - loss: 0.04
07 - accuracy: 0.9880
Epoch 8/10
60000/60000 [==============================] - 5s 89us/sample - loss: 0.03
44 - accuracy: 0.9896
Epoch 9/10
60000/60000 [==============================] - 5s 89us/sample - loss: 0.02
90 - accuracy: 0.9915
Epoch 10/10
60000/60000 [==============================] - 5s 89us/sample - loss: 0.02
52 - accuracy: 0.9923
```

Out[28]:

```
<tensorflow.python.keras.callbacks.History at 0x21d7e3ca608>
```

In [29]:

```
model.evaluate(X_test_flattened, y_test)
```

```
10000/10000 [==============================] - 1s 63us/sample - loss: 0.08
58 - accuracy: 0.9756
```

Out[29]:

```
[0.08582128985947929, 0.9756]
```

In [30]:

```
y_predicted = model.predict(X_test_flattened)
y_predicted_labels = [np.argmax(i) for i in y_predicted]
cm = tf.math.confusion_matrix(labels = y_test, predictions = y_predicted_labels)
cm
```

Out[30]:

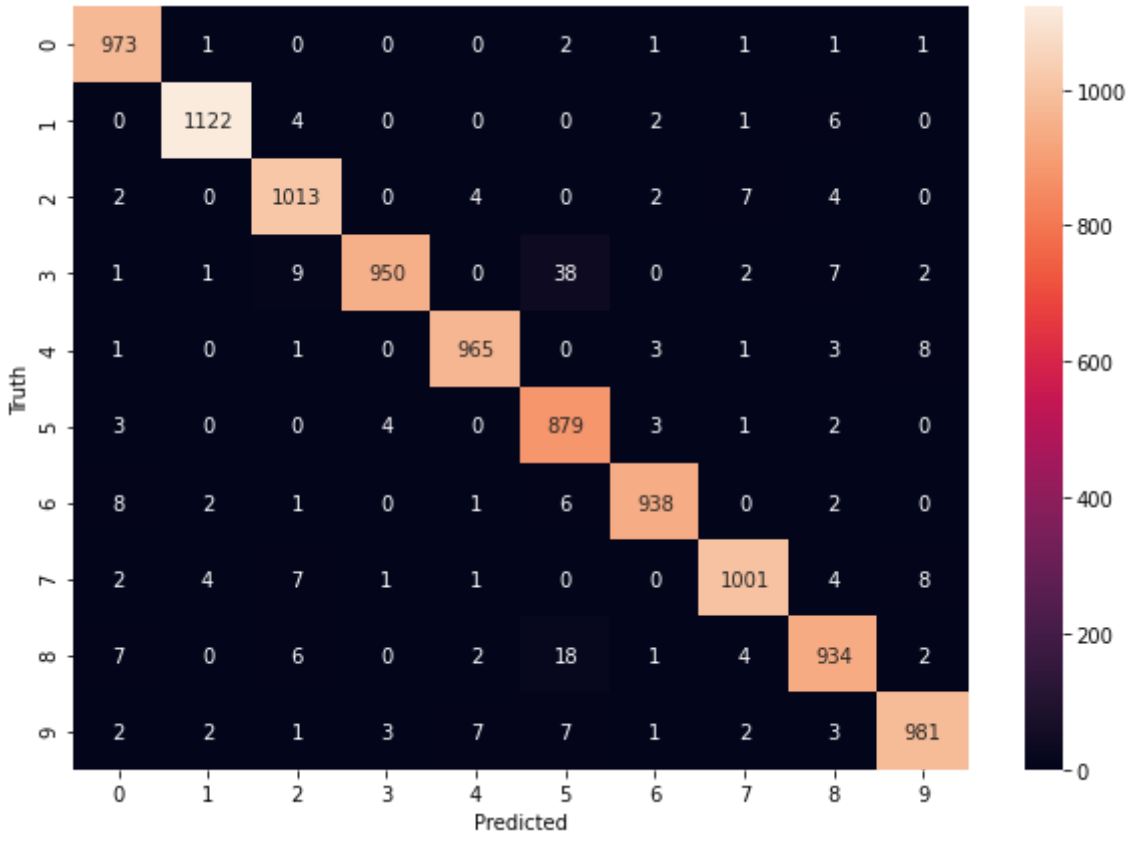
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 973,    1,    0,    0,    0,    2,    1,    1,    1,    1],
       [   0, 1122,    4,    0,    0,    0,    2,    1,    6,    0],
       [   2,    0, 1013,    0,    4,    0,    2,    7,    4,    0],
       [   1,    1,    9,  950,    0,   38,    0,    2,    7,    2],
       [   1,    0,    1,    0,  965,    0,    3,    1,    3,    8],
       [   3,    0,    0,    4,    0,  879,    3,    1,    2,    0],
       [   8,    2,    1,    0,    1,    6,  938,    0,    2,    0],
       [   2,    4,    7,    1,    1,    0,    0, 1001,    4,    8],
       [   7,    0,    6,    0,    2,   18,    1,    4,  934,    2],
       [   2,    2,    1,    3,    7,    7,    1,    2,    3,  981]])>
```

In [31]:

```
import seaborn as sn
plt.figure(figsize = (10, 7))
sn.heatmap(cm, annot = True, fmt = 'd')
plt.xlabel('Predicted')
plt.ylabel('Truth')
```

Out[31]:

```
Text(69.0, 0.5, 'Truth')
```



In [ ]: