Handwritten digits classification using neural network

In this notebook we will classify handwritten digits using a simple neural network which has only input and output layers. We will than add a hidden layer and see how the performance of the model improves

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()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11493376/11490434 [==============================] - 2s 0us/step
```

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

Out[3]: 60000

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

Out[4]: 10000

In [5]:
```
X_train[0].shape
```

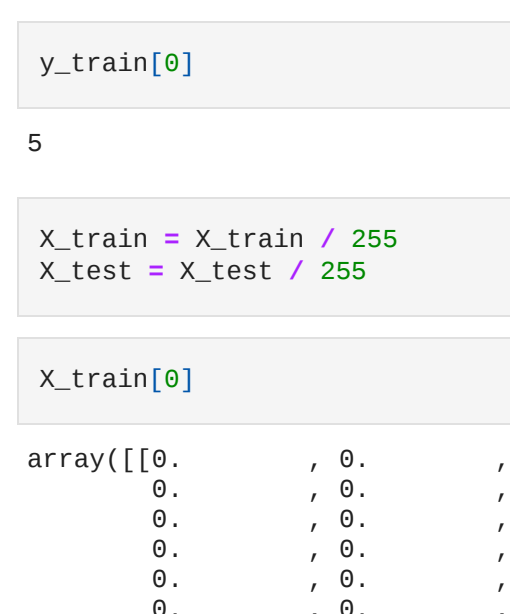
Out[5]: (28, 28)

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)
```

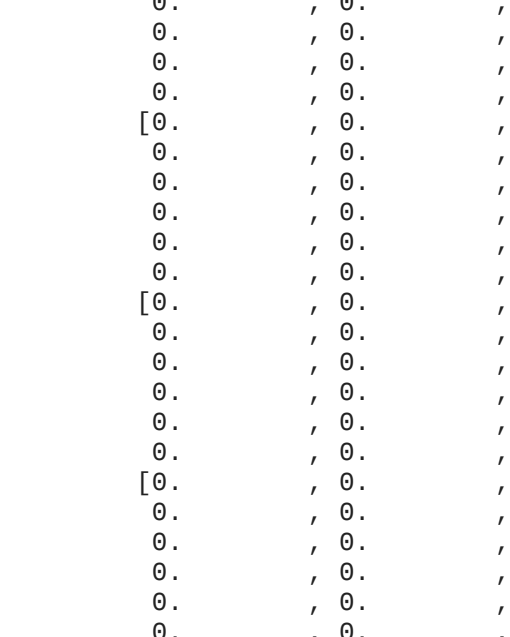
In [7]:
```
plt.matshow(X_train[0])
```

Out[7]: <matplotlib.image.AxesImage at 0x2a85f019100>



In [8]:
```
plt.matshow(X_train[1])
```

Out[8]: <matplotlib.image.AxesImage at 0x2a85f0ed130>



In [9]:
```
y_train[0]
```

Out[9]: 5

In [10]:
```
X_train = X_train / 255
X_test = X_test / 255
```

In [11]:
```
X_train[0]
```

Out[11]:
```
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, 0.77647059, 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.        , 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 [12]:
```
X_train_flattened = X_train.reshape(len(X_train), 28*28)
X_test_flattened = X_test.reshape(len(X_test), 28*28)
```

In [13]:
```
X_train_flattened.shape
```

Out[13]: (60000, 784)

In [14]:
```
X_train_flattened[0]
```

Out[14]:
```
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.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        , 0.        ,
       0.        , 0.        , 0.        , 0.        ])
```

In [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 [==============================] - 2s 1ms/step - loss: 0.4876 - accuracy: 0.8783
Epoch 2/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.3060 - accuracy: 0.9158
Epoch 3/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2849 - accuracy: 0.9210
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2747 - accuracy: 0.9237
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2671 - accuracy: 0.9257
```

Out[15]: <tensorflow.python.keras.callbacks.History at 0x2a85e761610>

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

```
  1/313 [..............................] - ETA: 0s - loss: 0.2761 - accuracy: 0.9688WARNING:tensorflow:Callbacks method `on_test_batch_end` is slow compared to the batch time (batc
h time: 0.0000s vs `on_test_batch_end` time: 0.0100s). Check your callbacks.
313/313 [==============================] - 0s 930us/step - loss: 0.2682 - accuracy: 0.9273
```

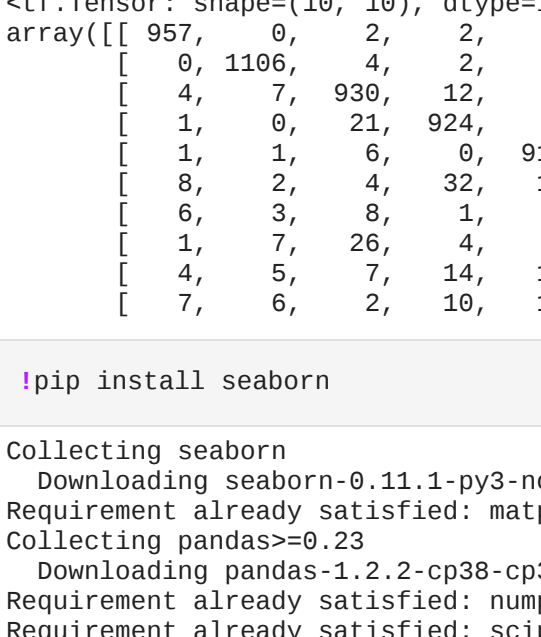
Out[16]: [0.2681877911090851, 0.927299976348877]

In [17]:
```
y_predicted = model.predict(X_test_flattened)
y_predicted[0]
```

Out[17]:
```
array([9.1807551e-06, 1.1243588e-10, 4.0124105e-05, 8.6890757e-03,
       1.3472301e-06, 8.3354549e-05, 1.4762296e-09, 7.1893895e-01,
       7.2274859e-05, 1.2923479e-03], dtype=float32)
```

In [18]:
```
plt.matshow(X_test[0])
```

Out[18]: <matplotlib.image.AxesImage at 0x2a85ebf7a00>



np.argmax finds a maximum element from an array and returns the index of it

In [19]:
```
np.argmax(y_predicted[0])
```

Out[19]: 7

In [20]:
```
y_predicted_labels = [np.argmax(i) for i in y_predicted]
```

In [21]:
```
y_predicted_labels[:5]
```

Out[21]: [7, 2, 1, 0, 4]

In [22]:
```
cm = tf.math.confusion_matrix(labels=y_test,predictions=y_predicted_labels)
cm
```

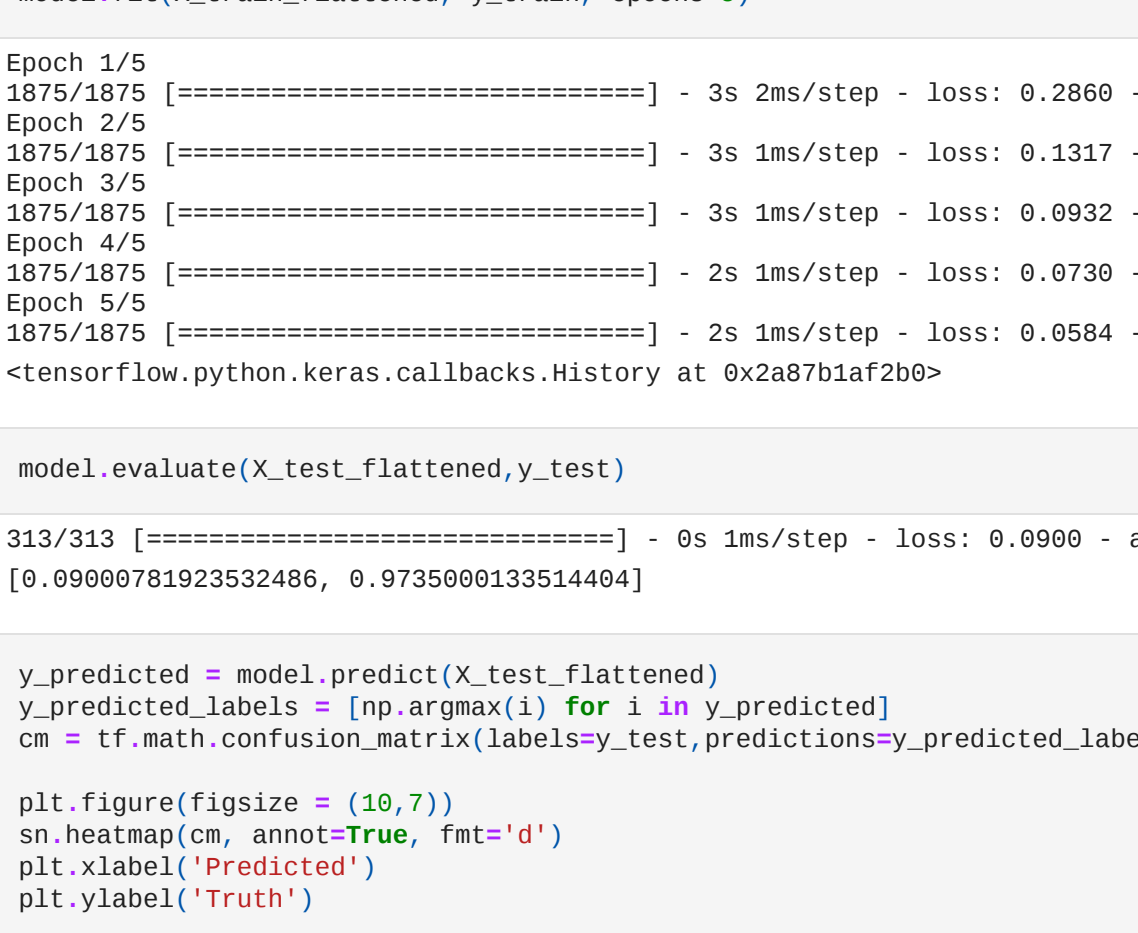
Out[22]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 957,    0,    2,    2,    0,    5,    7,    3,    3,    1],
       [   0, 1106,    4,    2,    0,    1,    4,    2,   16,    0],
       [   4,    7,  930,   12,    8,    4,   11,    9,   42,    5],
       [   1,    0,   21,  924,    1,   19,    2,    8,   19,   15],
       [   1,    1,    6,    0,  912,    0,    9,    3,    9,   41],
       [   8,    2,    4,   32,   11,  776,   13,    3,   34,    9],
       [   6,    3,    8,    1,    8,   14,  914,    2,    2,    0],
       [   1,    7,   26,    4,    8,    1,    0,  930,    2,   49],
       [   4,    5,    7,   14,   10,   20,    9,    9,  879,   17],
       [   7,    6,    2,   10,   19,    4,    0,    8,    8,  945]])>
```

In [24]:
```
!pip install seaborn
```

```
Collecting seaborn
  Downloading seaborn-0.11.1-py3-none-any.whl (285 kB)
Requirement already satisfied: matplotlib>=2.2 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from seaborn) (3.3.4)
Collecting pandas>=0.23
  Downloading pandas-1.2.2-cp38-cp38-win_amd64.whl (9.3 MB)
Requirement already satisfied: numpy>=1.15 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from seaborn) (1.19.2)
Requirement already satisfied: scipy>=1.0 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from seaborn) (1.6.0)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.3 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from matplotlib>=2.2->seaborn) (2.4.7)
Requirement already satisfied: python-dateutil>=2.1 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from matplotlib>=2.2->seaborn) (2.8.1)
Requirement already satisfied: kiwisolver>=1.0.1 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from matplotlib>=2.2->seaborn) (1.3.1)
Requirement already satisfied: pillow>=6.2.0 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from matplotlib>=2.2->seaborn) (8.1.0)
Requirement already satisfied: cycler>=0.10 in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from matplotlib>=2.2->seaborn) (0.10.0)
Requirement already satisfied: six in d:\programdata\anaconda3\envs\tensor\lib\site-packages (from cycler>=0.10->matplotlib>=2.2->seaborn) (1.15.0)
Collecting pytz>=2017.3
  Downloading pytz-2021.1-py2.py3-none-any.whl (510 kB)
Installing collected packages: pytz, pandas, seaborn
Successfully installed pandas-1.2.2 pytz-2021.1 seaborn-0.11.1
```

In [25]:
```
import seaborn as sn
plt.figure(figsize = (10,7))
sn.heatmap(cm, annot=True, fmt='d')
plt.xlabel('Predicted')
plt.ylabel('Truth')
```

Out[25]: Text(69.0, 0.5, 'Truth')



Using hidden layer

In [26]:
```
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)
```

```
Epoch 1/5
1875/1875 [==============================] - 3s 2ms/step - loss: 0.2860 - accuracy: 0.9196
Epoch 2/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.1317 - accuracy: 0.9612
Epoch 3/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.0932 - accuracy: 0.9719
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0730 - accuracy: 0.9781
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0584 - accuracy: 0.9825
```

Out[26]: <tensorflow.python.keras.callbacks.History at 0x2a87b1af2b0>

In [27]:
```
model.evaluate(X_test_flattened,y_test)
```

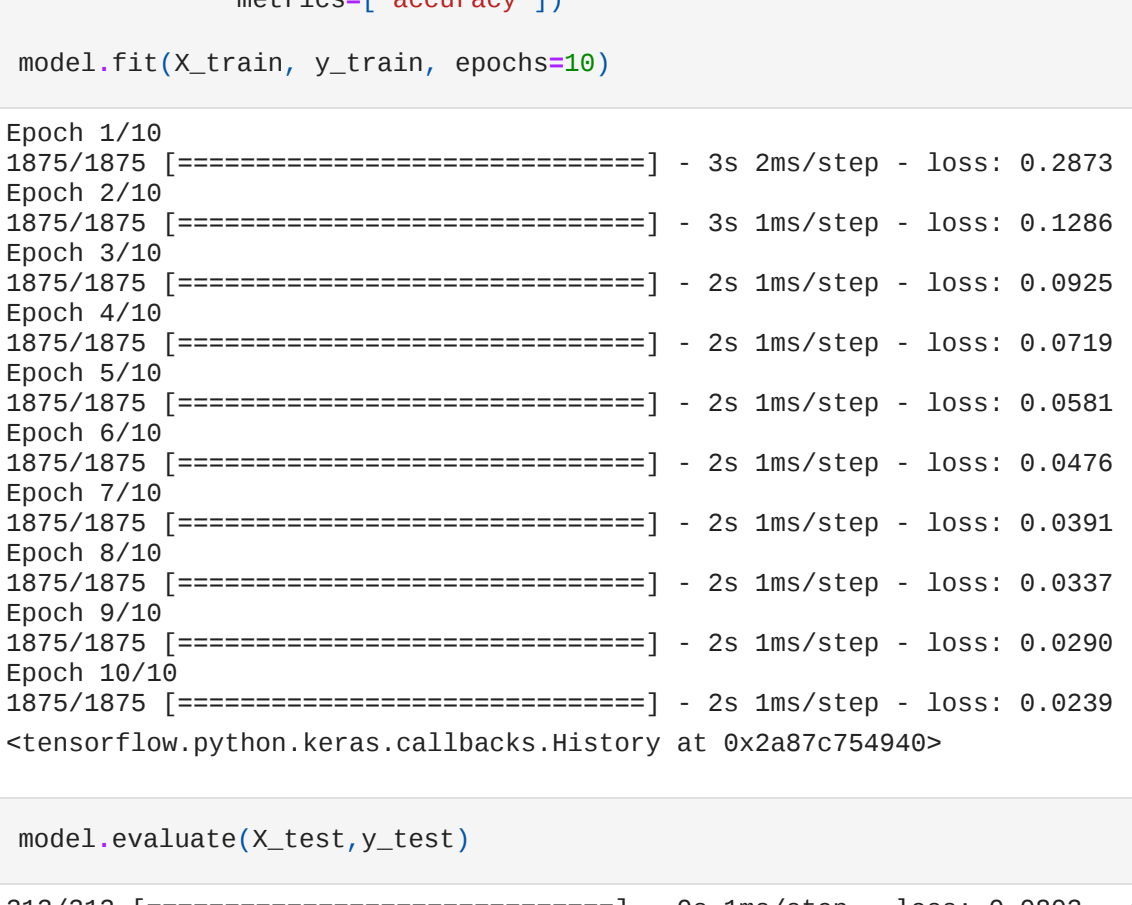
```
313/313 [==============================] - 0s 1ms/step - loss: 0.0900 - accuracy: 0.9735
```

Out[27]: [0.09000781923532486, 0.9735000133514404]

In [28]:
```
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)

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

Out[28]: Text(69.0, 0.5, 'Truth')



Using Flatten layer so that we don't have to call .reshape on input dataset

In [29]:
```
model = keras.Sequential([
    keras.layers.Flatten(input_shape=(28, 28)),
    keras.layers.Dense(100, 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=10)
```

```
Epoch 1/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.2873 - accuracy: 0.9202
Epoch 2/10
1875/1875 [==============================] - 3s 1ms/step - loss: 0.1286 - accuracy: 0.9633
Epoch 3/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0925 - accuracy: 0.9726
Epoch 4/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0719 - accuracy: 0.9784
Epoch 5/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0581 - accuracy: 0.9824
Epoch 6/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0476 - accuracy: 0.9856
Epoch 7/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0391 - accuracy: 0.9889
Epoch 8/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0337 - accuracy: 0.9894
Epoch 9/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0290 - accuracy: 0.9909
Epoch 10/10
1875/1875 [==============================] - 2s 1ms/step - loss: 0.0239 - accuracy: 0.9929
```

Out[29]: <tensorflow.python.keras.callbacks.History at 0x2a87c754940>

In [30]:
```
model.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 0s 1ms/step - loss: 0.0803 - accuracy: 0.9772
```

Out[30]: [0.08026491850614548, 0.9771999716758728]

In [ ]: