Master of Technology
In
Data and Computational Science

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Fractal-3 Assignment

Problem 2: Learning to implement Neural Network [30 points]
1. Gurmukhi Handwritten Digit Classification: Gurmukhi is one of the popular Indian scripts widely used in Indian state of Punjab. In this part of the assignment, our goal is to develop a neural network solution (a simple NN, not a CNN) for classifying Gurmukhi digits. We provide you Handwritten Gurmukhi digit dataset here:

Dataset link
Modify the code provided in here and a video tutorial here, and develop a robust neural network to classify the Gurmukhi digits. Higher performance on test set will have bonus point. Briefly write your observation and submit your code so that we can evaluate your implementation at our end.

[Upload files · DebicharanTripathy/Fractal-3-Assignment (github.com)]()

Learning to implement Neural Network

```
In [29]: import tensorflow as tf
         from tensorflow import keras
         import matplotlib.pyplot as plt
         %matplotlib inline
         import numpy as np
```

```
In [3]: (X_train, y_train) , (X_test, y_test) = keras.datasets.mnist.load_data()
```

```
In [4]: len(X_train)
Out[4]: 60000
```

```
In [5]: len(X_test)
Out[5]: 10000
```

```
In [6]: X_train[0].shape
Out[6]: (28, 28)
```

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

```
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],
```

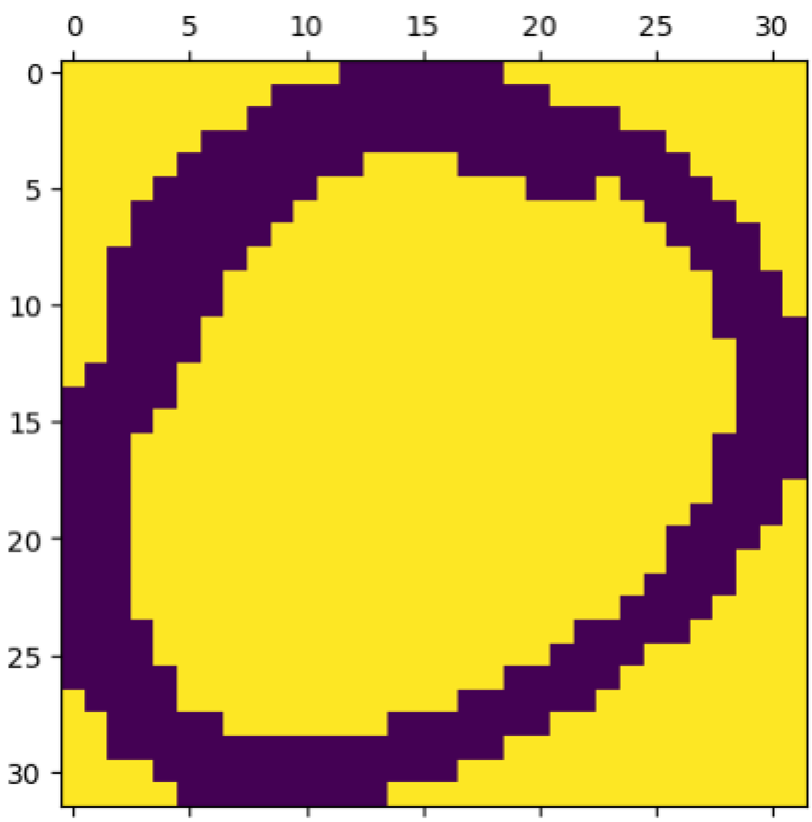
```
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,  16,  93, 252, 253, 187,   0,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,   0,
   0,   0,   0,   0, 249, 253, 249,  64,   0,   0,   0,   0,   0,
   0,   0],
[  0,   0,   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)
```

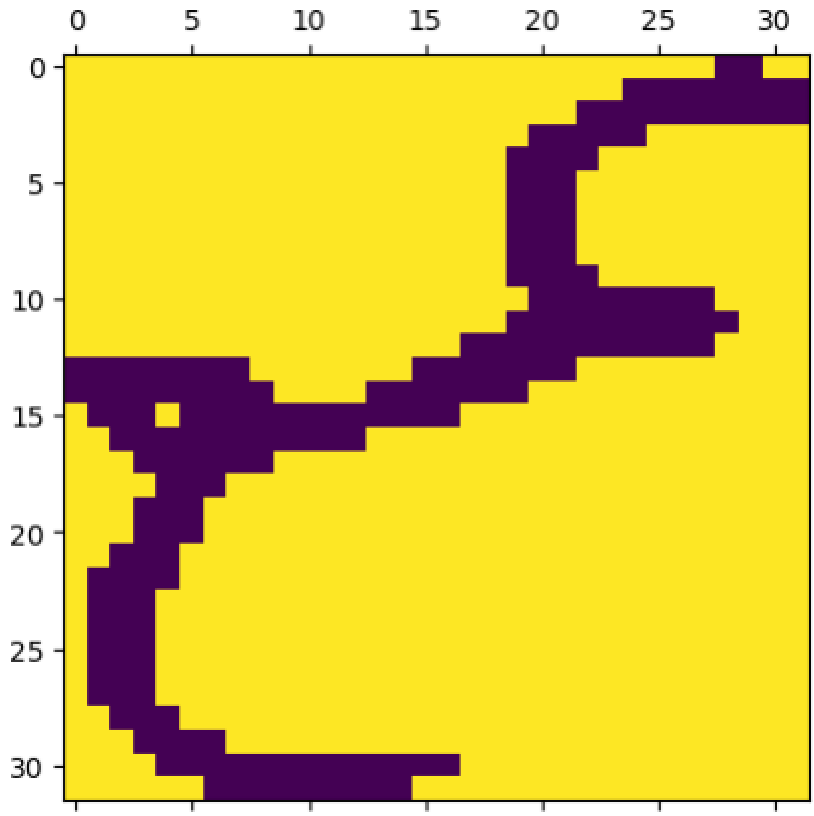
```
# Load the dataset
x_train = np.load('x_train.npy')
y_train = np.load('y_train.npy')
x_test = np.load('x_test.npy')
y_test = np.load('y_test.npy')
```

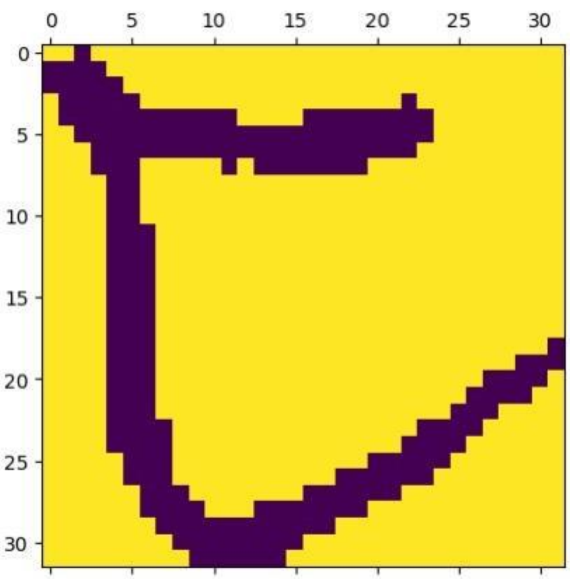
```
# test the images are loaded correctly

print(len(x_train))
print(len(x_test))
x_train[0].shape
x_train[0]
plt.matshow(x_train[0])
plt.matshow(x_train[999])
print(x_train.shape)
print(x_test.shape)
y_train
y_test
plt.matshow(x_test[150])
```

```
1000
178
(1000, 32, 32)
(178, 32, 32)
<matplotlib.image.AxesImage at 0x20ba468abb0>
```




0
5
10
15
20
25
30




```
# # flatten the dataset i.e, change 2D to 1D (skipped this , and flattened in the model)

# x_train_flat = x_train.reshape(len(x_train),32*32)
# x_test_flat = x_test.reshape(len(x_test),32*32)

# print(x_train_flat.shape)
# print(x_test_flat.shape)

# x_train_flat[0]
```

```
# creating a simple nn
# create a dense layer where every input is connected to every other output, the number of inputs are 1000, outputs are 10
# activation function is sigmoid

model = keras.Sequential([
    keras.layers.Flatten(),
```

```
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.        ,
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        0.07058824, 0.49411765, 0.53333333, 0.68627451, 0.10196078,
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        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.        , 0.        , 0.        , 0.        , 0.        ,
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 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.        ,
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 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
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 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.        ,
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 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,
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 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
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 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
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 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.97647059, 0.99215686, 0.97647059,
```

```
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.18039216,
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 0.00784314, 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
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 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
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 0.77647059, 0.31764706, 0.00784314, 0.        , 0.        ,
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 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
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 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,
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 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        ],
[0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
 0.        , 0.        , 0.        , 0.        , 0.        ,
```

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

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

In [14]:

```
X_train_flattened.shape
```

Out[14]:

```
(60000, 784)
```

In [15]:

```
X_train_flattened[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.        ,
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               0.        , 0.        , 0.        , 0.        , 0.        ,
               0.        , 0.        , 0.        , 0.        , 0.        ,
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               0.07058824, 0.49411765, 0.53333333, 0.68627451, 0.10196078,
               0.65098039, 1.        , 0.96862745, 0.49803922, 0.        ,
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               0.66666667, 0.99215686, 0.99215686, 0.99215686, 0.99215686,
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               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.        ,
```

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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.        ,
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0.        , 0.        , 0.        , 0.        , 0.54509804,
0.99215686, 0.74509804, 0.00784314, 0.        , 0.        ,
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0.        , 0.        , 0.04313725, 0.74509804, 0.99215686,
0.2745098 , 0.        , 0.        , 0.        , 0.        ,
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0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.1372549 , 0.94509804, 0.88235294, 0.62745098,
0.42352941, 0.00392157, 0.        , 0.        , 0.        ,
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0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
0.31764706, 0.94117647, 0.99215686, 0.99215686, 0.46666667,
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0.        , 0.        , 0.        , 0.        , 0.        ,
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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.        ,
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0.        , 0.        , 0.        , 0.0627451 , 0.36470588,
0.98823529, 0.99215686, 0.73333333, 0.        , 0.        ,
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0.        , 0.        , 0.        , 0.        , 0.        ,
0.        , 0.        , 0.        , 0.        , 0.        ,
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0.98039216, 0.71372549, 0.        , 0.        , 0.        ,
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0.        , 0.        , 0.        , 0.        , 0.        ,
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0.        , 0.        , 0.        , 0.        , 0.        ,
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0.99215686, 0.99215686, 0.99215686, 0.77647059, 0.31764706,
0.00784314, 0.        , 0.        , 0.        , 0.        ,
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0.        , 0.        , 0.07058824, 0.67058824, 0.85882353,
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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.        ,
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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.        ,
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```

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

In [45]:
```
model = keras.Sequential([
    keras.layers.Dense(10, input_shape=(784,), activation='sigmoid')
])

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

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

```
Epoch 1/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.4886 - accuracy: 0.8775
Epoch 2/5
1875/1875 [==============================] - 3s 1ms/step - loss: 0.3060 - accuracy: 0.9156
Epoch 3/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2848 - accuracy: 0.9214
Epoch 4/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2747 - accuracy: 0.9243
Epoch 5/5
1875/1875 [==============================] - 2s 1ms/step - loss: 0.2677 - accuracy: 0.9262
```

Out[45]: <tensorflow.python.keras.callbacks.History at 0x1fe24f47a90>

In [46]:
```
model.evaluate(X_test_flattened, y_test)
```

```
313/313 [==============================] - 0s 985us/step - loss: 0.2670 - accuracy: 0.9257
```

Out[46]: [0.26697656512260437, 0.9257000088691711]

In [47]:
```
y_predicted = model.predict(X_test_flattened)
y_predicted[0]
```

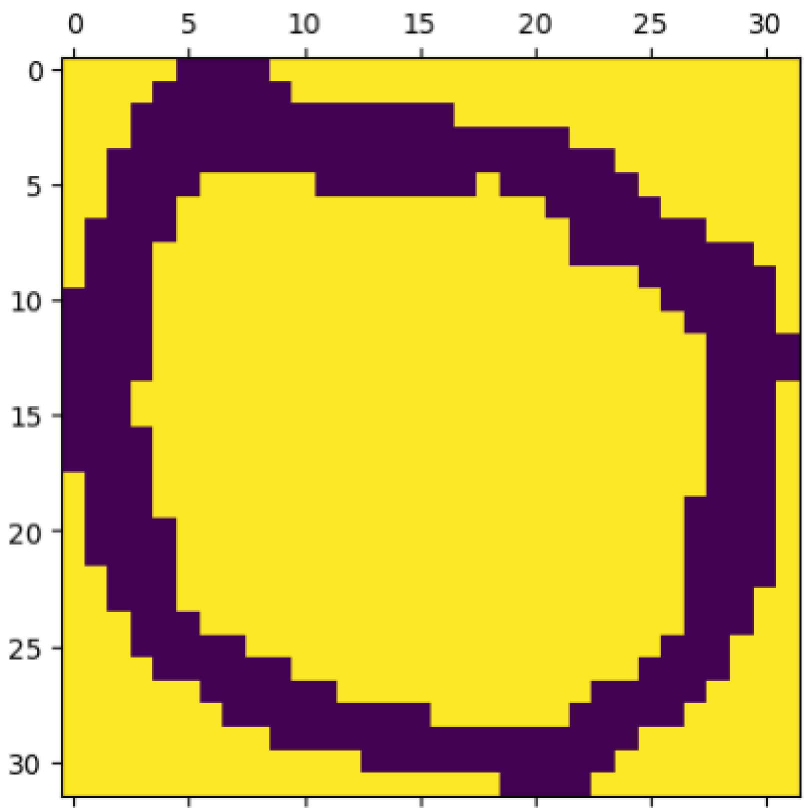
Out[47]:
```
array([1.7270680e-05, 1.3593615e-10, 4.5622761e-05, 7.5602829e-03,
       1.3076769e-06, 7.5061922e-05, 1.7646971e-09, 6.9968843e-01,
       7.8440302e-05, 8.1232190e-04], dtype=float32)
```

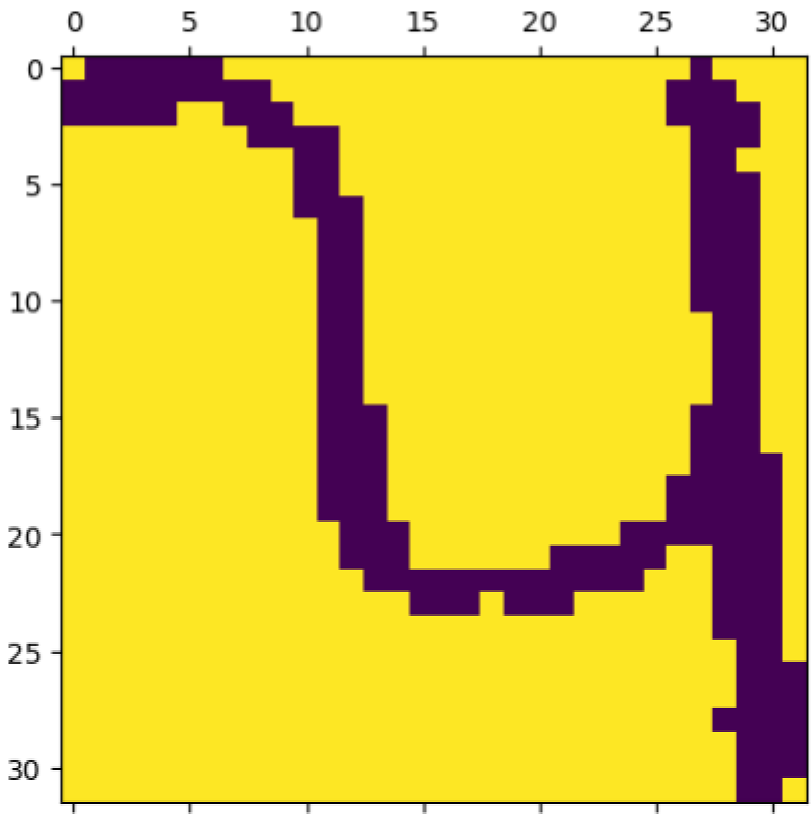
In [48]:
```
plt.matshow(X_test[0])
```

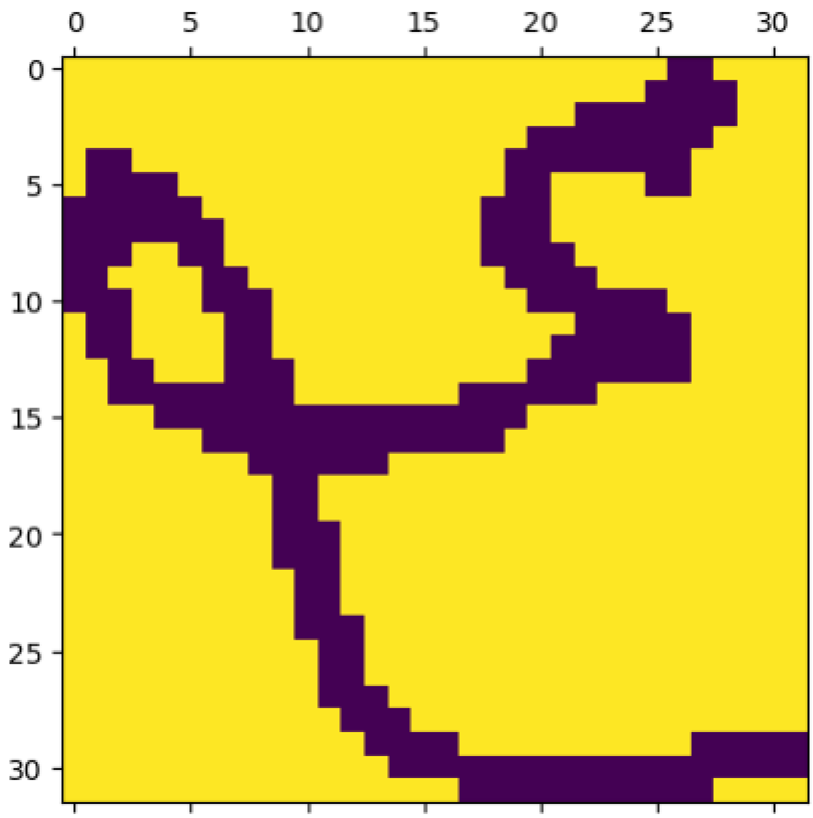
```
# Observation : result almost same as the training dataset,
```

```
# predict 1st image

plt.matshow(x_test[0])

y_predicted = model.predict(x_test_scaled)
y_predicted[0]

# this showing the 10 results for the input '0', we need to look for the value which is max

print('Predicted Value is ',np.argmax(y_predicted[0]))

# test some more values

plt.matshow(x_test[88])
print('Predicted Value is ',np.argmax(y_predicted[88]))

plt.matshow(x_test[177])
print('Predicted Value is ',np.argmax(y_predicted[177]))
```

```
6/6 [==============================] - 0s 3ms/step
Predicted Value is  0
Predicted Value is  5
Predicted Value is  9
```




0
5
10
15
20
25
30
0
5
10
15
20
25
30

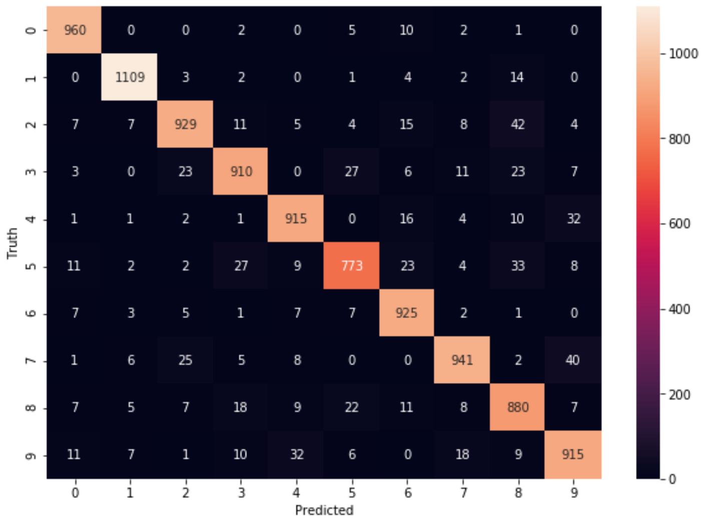


```
# some predictions may not be not right

# build confusion matrix to see how our prediction looks like

# convert to concrete values
y_predicted_labels=[np.argmax(i) for i in y_predicted]

print(y_predicted_labels, len(y_predicted_labels))

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

Out[52]:
```
<tf.Tensor: shape=(10, 10), dtype=int32, numpy=
array([[ 960,    0,    0,    2,    0,    5,   10,    2,    1,    0],
       [   0, 1109,    3,    2,    0,    1,    4,    2,   14,    0],
       [   7,    7,  929,   11,    5,    4,   15,    8,   42,    4],
       [   3,    0,   23,  910,    0,   27,    6,   11,   23,    7],
       [   1,    1,    2,    1,  915,    0,   16,    4,   10,   32],
       [  11,    2,    2,   27,    9,  773,   23,    4,   33,    8],
       [   7,    3,    5,    1,    7,    7,  925,    2,    1,    0],
       [   1,    6,   25,    5,    8,    0,    0,  941,    2,   40],
       [   7,    5,    7,   18,    9,   22,   11,    8,  880,    7],
       [  11,    7,    1,   10,   32,    6,    0,   18,    9,  915]])>
```

In [53]:
```
import seaborn as sn
plt.figure(figsize = (10,7))
sn.heatmap(cm, annot=True, fmt='d')
plt.xlabel('Predicted')
plt.ylabel('Truth')
```

Out[53]: Text(69.0, 0.5, 'Truth')



Using hidden layer

In [54]:
```
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: 0.2925 - accuracy: 0.9191
Epoch 2/5
1875/1875 [==============================] - 3s 2ms/step - loss: 0.1366 - accuracy: 0.9602
Epoch 3/5
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0981 - accuracy: 0.9703
Epoch 4/5
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0764 - accuracy: 0.9768
Epoch 5/5
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0618 - accuracy: 0.9812
```

Out[54]: <tensorflow.python.keras.callbacks.History at 0x1fe230e7128>

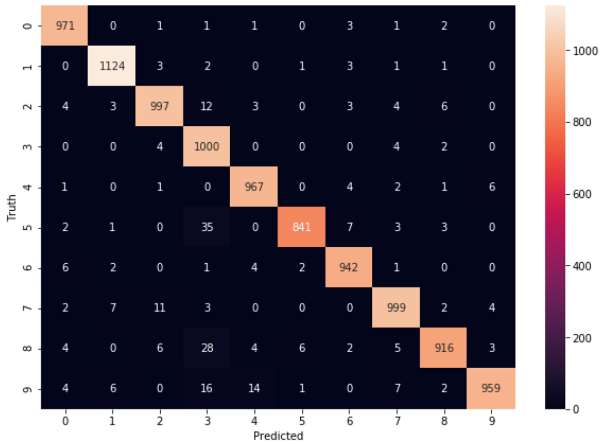
In [55]:
```
model.evaluate(X_test_flattened,y_test)
```

```
313/313 [==============================] - 0s 1ms/step - loss: 0.0966 - accuracy: 0.9716
```

Out[55]: [0.09658893942832947, 0.9715999960899353]

In [56]:
```
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[56]: Text(69.0, 0.5, 'Truth')
```



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

```
In [59]: 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: 0.2959 - accuracy: 0.9185
Epoch 2/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.1368 - accuracy: 0.9603
Epoch 3/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0995 - accuracy: 0.9703
Epoch 4/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0771 - accuracy: 0.9772
Epoch 5/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0628 - accuracy: 0.9806
Epoch 6/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0519 - accuracy: 0.9841
Epoch 7/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0442 - accuracy: 0.9865
Epoch 8/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0369 - accuracy: 0.9886
Epoch 9/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0300 - accuracy: 0.9910
Epoch 10/10
1875/1875 [==============================] - 3s 2ms/step - loss: 0.0264 - accuracy: 0.9917
Out[59]: <tensorflow.python.keras.callbacks.History at 0x1fe24629e80>
```

```
In [60]: model.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 0s 1ms/step - loss: 0.0813 - accuracy: 0.9779
Out[60]: [0.08133944123983383, 0.9779000282287598]
```

===