Lab-2

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LAB-2: Creating a Convolutional Nueral Network to classify digits in a MNIST dataset.

Data from: https://github.com/myleott/mnist_png/raw/master/

1) Import Libraries

[ ]:
```python
import gzip
import numpy as np
import tensorflow as tf
from tensorflow.keras import layers, models
import matplotlib.pyplot as plt
```

2) Define Custom Functions.

[ ]:
```python
def load_mnist_images(filename):
    with gzip.open(filename, 'rb') as f:
        data = np.frombuffer(f.read(), dtype=np.uint8, offset=16)
    return data.reshape(-1, 28, 28)
```

[ ]:
```python
def load_mnist_labels(filename):
    with gzip.open(filename, 'rb') as f:
        labels = np.frombuffer(f.read(), dtype=np.uint8, offset=8)
    return labels
```

3) Load training data

[ ]:
```python
train_X = load_mnist_images('train-images-idx3-ubyte.gz')
train_y = load_mnist_labels('train-labels-idx1-ubyte.gz')
```

4) Load testing data

[ ]:
```python
test_X = load_mnist_images('t10k-images-idx3-ubyte.gz')
test_y = load_mnist_labels('t10k-labels-idx1-ubyte.gz')
```

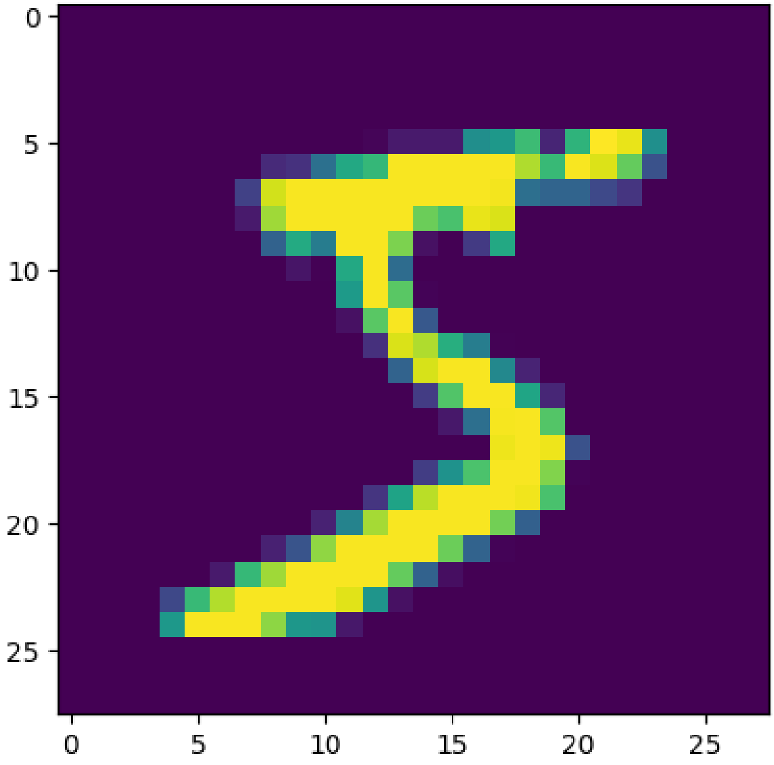
5) Explore Data

[ ]:
```python
print('X_train shape:', train_X.shape)
print('Y_train shape:', train_y.shape)
print('X_test shape:', test_X.shape)
print('Y_test shape:', test_y.shape)
```

```
X_train shape: (60000, 28, 28)
Y_train shape: (60000,)
X_test shape: (10000, 28, 28)
Y_test shape: (10000,)
```

```
[ ]: plt.imshow(train_X[0])
```

```
[ ]: <matplotlib.image.AxesImage at 0x1d3e966c9d0>
```



```
[ ]: train_X[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)
```

6) Preprocess the data

[ ]:

```
# The original pixel values range from 0 to 255 (since they are grayscale␣
 ↪images).
# Dividing each pixel value by 255.0 normalizes them to the range [0, 1].
# Normalization helps the neural network converge faster during training and␣
 ↪ensures that all features have a similar scale.

train_X = train_X / 255.0
test_X = test_X / 255.0
```

7) Handle categorical values:

[ ]:

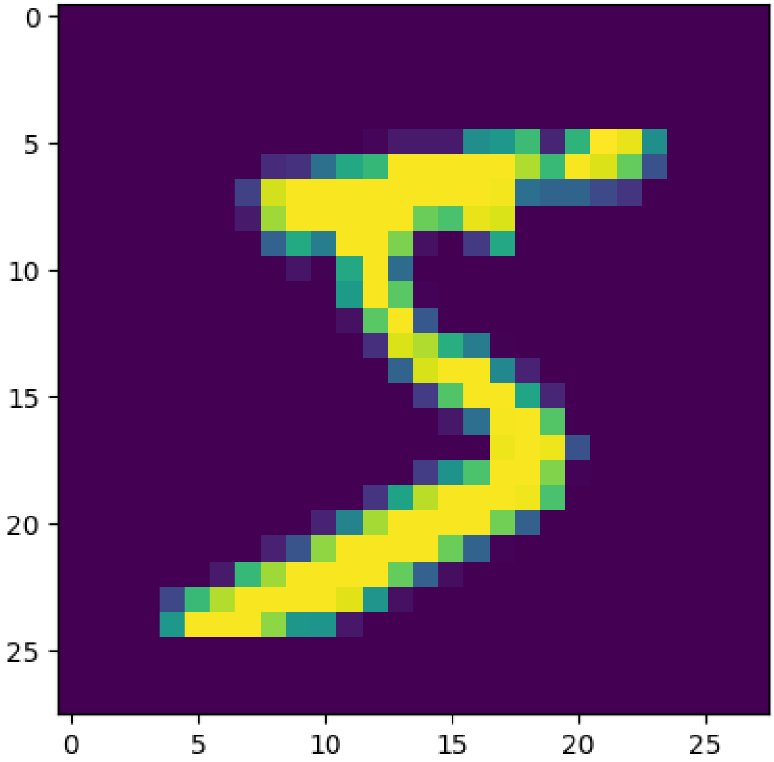
```
# The train_y and test_y variable contains the labels (target values) for the␣
 ↪training data.
# The MNIST dataset has 10 classes (digits 0 to 9).
# to_categorical converts the integer labels (0 to 9) into one-hot encoded␣
 ↪vectors.
# For example, if the original label is 3, it will be converted to [0, 0, 0, 1,␣
 ↪0, 0, 0, 0, 0, 0].
```

```
train_y = tf.keras.utils.to_categorical(train_y, 10)
test_y = tf.keras.utils.to_categorical(test_y, 10)
```

8) See image after preprocessing

```
[ ]: plt.imshow(train_X[0])
```

```
[ ]: <matplotlib.image.AxesImage at 0x1d3e9757f10>
```



9) Build Model

```
[ ]: model = models.Sequential()
     model.add(layers.Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28, 1)))
     model.add(layers.MaxPooling2D((2, 2)))
     model.add(layers.Flatten())
     model.add(layers.Dense(128, activation='relu'))
     model.add(layers.Dense(10, activation='softmax'))
```

```
[ ]: model.summary()
```

```
Model: "sequential_1"

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_1 (Conv2D)           (None, 26, 26, 32)        320

 max_pooling2d_1 (MaxPoolin  (None, 13, 13, 32)        0
 g2D)

 flatten_1 (Flatten)         (None, 5408)              0

 dense_2 (Dense)             (None, 128)               692352

 dense_3 (Dense)             (None, 10)                1290

=================================================================
Total params: 693962 (2.65 MB)
Trainable params: 693962 (2.65 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

10) Compile the model

[ ]:
```
model.compile(optimizer='adam',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

11) Train the model

[ ]:
```
model.fit(train_X, train_y, epochs=5, batch_size=64, validation_split=0.2)
```

```
Epoch 1/5
750/750 [==============================] - 9s 11ms/step - loss: 0.2034 -
accuracy: 0.9399 - val_loss: 0.0797 - val_accuracy: 0.9760
Epoch 2/5
750/750 [==============================] - 9s 11ms/step - loss: 0.0636 -
accuracy: 0.9808 - val_loss: 0.0649 - val_accuracy: 0.9812
Epoch 3/5
750/750 [==============================] - 8s 11ms/step - loss: 0.0429 -
accuracy: 0.9870 - val_loss: 0.0574 - val_accuracy: 0.9832
Epoch 4/5
750/750 [==============================] - 8s 11ms/step - loss: 0.0293 -
accuracy: 0.9909 - val_loss: 0.0640 - val_accuracy: 0.9828
Epoch 5/5
750/750 [==============================] - 8s 10ms/step - loss: 0.0220 -
accuracy: 0.9927 - val_loss: 0.0595 - val_accuracy: 0.9843
```

[ ]:
```
<keras.src.callbacks.History at 0x1d3e96c1e90>
```

12) Evaluate model

[ ]:
```
test_loss, test_acc = model.evaluate(test_X, test_y)
print(f"Test accuracy: {test_acc:.4f}")
```

```
313/313 [==============================] - 1s 4ms/step - loss: 0.0469 -
accuracy: 0.9845
Test accuracy: 0.9845
```

```
[ ]: result = model.predict(test_X[:5])
     result
```

```
1/1 [==============================] - 0s 63ms/step
```

```
[ ]: array([[1.04813402e-07, 1.84427563e-07, 2.83185491e-05, 6.71027577e-04,
             9.31887068e-11, 3.59124774e-09, 9.64180385e-12, 9.99274433e-01,
             1.60632771e-05, 9.90389890e-06],
            [1.13121885e-07, 8.95087567e-07, 9.99998689e-01, 2.82874577e-08,
             6.41105482e-14, 5.17818344e-10, 2.85112769e-08, 1.24928526e-10,
             2.12520234e-07, 3.05248500e-11],
            [4.07579847e-07, 9.99946594e-01, 6.43619728e-07, 3.27660317e-08,
             8.22047605e-06, 7.21620736e-08, 5.14932537e-07, 3.20113941e-05,
             1.13063270e-05, 1.19408455e-07],
            [9.99929428e-01, 8.22772463e-08, 9.36876040e-06, 7.05414109e-08,
             2.44477025e-08, 5.45666694e-08, 5.92751603e-05, 1.84827336e-08,
             6.45311786e-07, 1.02698891e-06],
            [1.84190851e-09, 1.40418850e-08, 6.47186766e-07, 1.36184099e-07,
             9.99997497e-01, 1.95557237e-10, 5.26553876e-08, 1.38565824e-07,
             5.01484067e-07, 1.01938895e-06]], dtype=float32)
```

```
[ ]: test_y[:5]
```

```
[ ]: array([[0., 0., 0., 0., 0., 0., 0., 1., 0., 0.],
            [0., 0., 1., 0., 0., 0., 0., 0., 0., 0.],
            [0., 1., 0., 0., 0., 0., 0., 0., 0., 0.],
            [1., 0., 0., 0., 0., 0., 0., 0., 0., 0.],
            [0., 0., 0., 0., 1., 0., 0., 0., 0., 0.]], dtype=float32)
```

```
[ ]: result.argmax(axis=1)
```

```
[ ]: array([7, 2, 1, 0, 4], dtype=int64)
```

```
[ ]: test_y[:10].argmax(axis=1)
```

```
[ ]: array([7, 2, 1, 0, 4, 1, 4, 9, 5, 9], dtype=int64)
```