In [ ]:
```
import numpy as np
import pandas as pd
import random
import tensorflow as tf
import matplotlib.pyplot as plt
```

```
2022-11-01 14:39:54.742698: I tensorflow/core/platform/cpu_feature_guard.cc:193] This TensorFlow binary is opti
mized with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-cri
tical operations:  AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.
2022-11-01 14:39:54.931898: E tensorflow/stream_executor/cuda/cuda_blas.cc:2981] Unable to register cuBLAS fact
ory: Attempting to register factory for plugin cuBLAS when one has already been registered
2022-11-01 14:39:55.606705: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dyna
mic library 'libnvinfer.so.7'; dlerror: libnvinfer.so.7: cannot open shared object file: No such file or direct
ory
2022-11-01 14:39:55.606775: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dyna
mic library 'libnvinfer_plugin.so.7'; dlerror: libnvinfer_plugin.so.7: cannot open shared object file: No such
file or directory
2022-11-01 14:39:55.606784: W tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Cannot dlop
en some TensorRT libraries. If you would like to use Nvidia GPU with TensorRT, please make sure the missing lib
raries mentioned above are installed properly.
```

In [ ]:
```
from sklearn.metrics import accuracy_score
```

In [ ]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Flatten, Conv2D, Dense, MaxPooling2D
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.datasets import mnist
```

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

In [ ]:
```
print(X_train.shape)
(60000, 28, 28)
```

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

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

In [ ]:
```
print(X_train.shape)
```

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

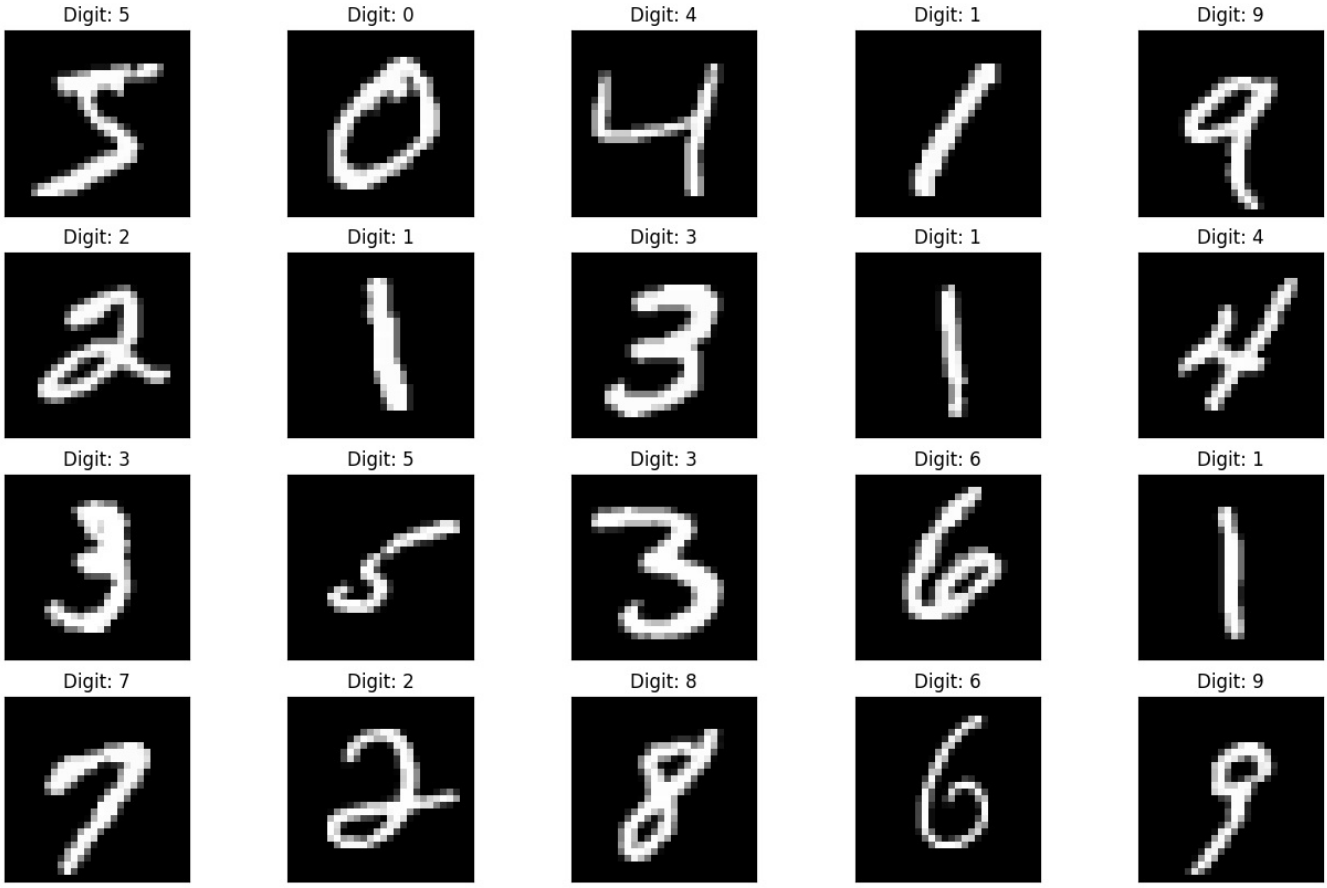
In [ ]:
```
X_train[0].min(), X_train[0].max()
```

Out[ ]:
```
(0, 255)
```

In [ ]:
```
X_train = (X_train - 0.0) / (255.0 - 0.0)
X_test = (X_test - 0.0) / (255.0 - 0.0)
X_train[0].min(), X_train[0].max()
```

Out[ ]:
```
(0.0, 1.0)
```

In [ ]:
```
def plot_digit(image, digit, plt, i):
    plt.subplot(4, 5, i + 1)
    plt.imshow(image, cmap=plt.get_cmap('gray'))
    plt.title(f"Digit: {digit}")
    plt.xticks([])
    plt.yticks([])
plt.figure(figsize=(16, 10))
for i in range(20):
    plot_digit(X_train[i], y_train[i], plt, i)
plt.show()
```



In [ ]:
```
X_train = X_train.reshape((X_train.shape + (1,)))
X_test = X_test.reshape((X_test.shape + (1,)))
```

In [ ]:
```
y_train[0:20]
```

Out[ ]:
```
array([5, 0, 4, 1, 9, 2, 1, 3, 1, 4, 3, 5, 3, 6, 1, 7, 2, 8, 6, 9],
      dtype=uint8)
```

In [ ]:
```
model = Sequential([
    Conv2D(32, (3, 3), activation="relu", input_shape=(28, 28, 1)),
    MaxPooling2D((2, 2)),
    Flatten(),
    Dense(100, activation="relu"),
    Dense(10, activation="softmax")
])
```

```
2022-11-01 14:39:58.752732: E tensorflow/stream_executor/cuda/cuda_driver.cc:265] failed call to cuInit: CUDA_E
RROR_NO_DEVICE: no CUDA-capable device is detected
2022-11-01 14:39:58.752763: I tensorflow/stream_executor/cuda/cuda_diagnostics.cc:156] kernel driver does not a
ppear to be running on this host (turing-machine): /proc/driver/nvidia/version does not exist
2022-11-01 14:39:58.753590: I tensorflow/core/platform/cpu_feature_guard.cc:193] This TensorFlow binary is opti
mized with oneAPI Deep Neural Network Library (oneDNN) to use the following CPU instructions in performance-cri
tical operations:  AVX2 FMA
To enable them in other operations, rebuild TensorFlow with the appropriate compiler flags.
```

In [ ]:
```
optimizer = SGD(learning_rate=0.01, momentum=0.9)
model.compile(
    optimizer=optimizer,
    loss="sparse_categorical_crossentropy",
    metrics=["accuracy"]
)
```

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

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 26, 26, 32)        320

 max_pooling2d (MaxPooling2D  (None, 13, 13, 32)       0
 )

 flatten (Flatten)           (None, 5408)              0

 dense (Dense)               (None, 100)               540900

 dense_1 (Dense)             (None, 10)                1010

=================================================================
Total params: 542,230
Trainable params: 542,230
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:
```
model.fit(X_train, y_train, epochs=5, batch_size=32)
```

```
Epoch 1/5
2022-11-01 14:39:59.122464: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocation of 188160000 excee
ds 10% of free system memory.
1875/1875 [==============================] - 11s 6ms/step - loss: 0.2364 - accuracy: 0.9278
Epoch 2/5
1875/1875 [==============================] - 11s 6ms/step - loss: 0.0779 - accuracy: 0.9763
Epoch 3/5
1875/1875 [==============================] - 10s 6ms/step - loss: 0.0502 - accuracy: 0.9847
Epoch 4/5
1875/1875 [==============================] - 11s 6ms/step - loss: 0.0363 - accuracy: 0.9889
Epoch 5/5
1875/1875 [==============================] - 10s 6ms/step - loss: 0.0267 - accuracy: 0.9916
```

Out[ ]:
```
<keras.callbacks.History at 0x7f4f34a4f310>
```

In [ ]:
```
plt.figure(figsize=(16, 10))
for i in range(20):
    image = random.choice(X_test).squeeze()
    digit = np.argmax(model.predict(image.reshape((1, 28, 28, 1)))[0], axis=-1)
    plot_digit(image, digit, plt, i)
plt.show()
```

```
1/1 [==============================] - 0s 64ms/step
1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 18ms/step
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1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 16ms/step
1/1 [==============================] - 0s 16ms/step
```

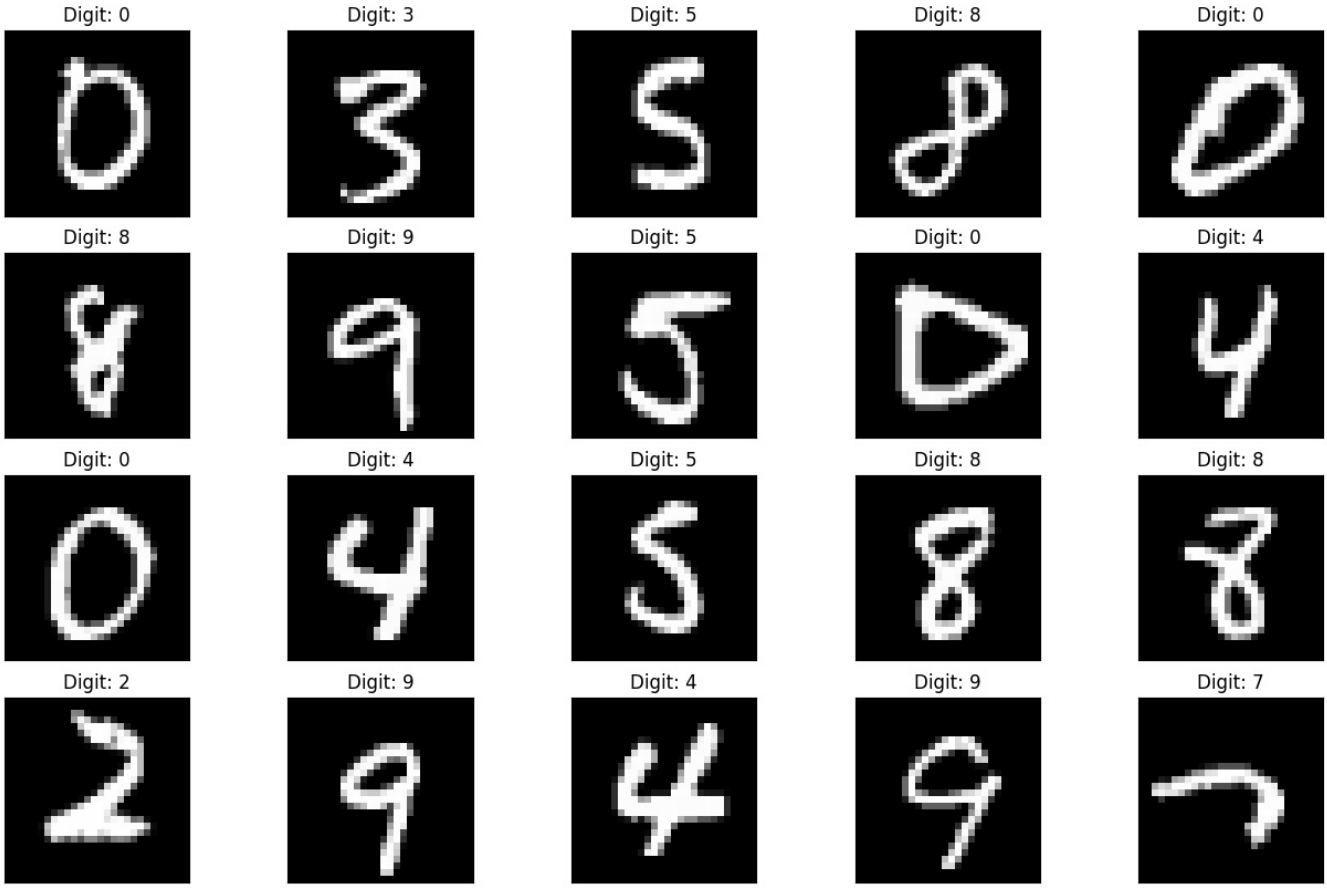

In [ ]:
```
predictions = np.argmax(model.predict(X_test), axis=-1)
accuracy_score(y_test, predictions)
```

```
 60/313 [====>.....................] - ETA: 0s
2022-11-01 14:40:54.203620: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocation of 31360000 exceeds 10% of free system memory.
313/313 [==============================] - 1s 3ms/step
```

Out[ ]:
```
0.9839
```

In [ ]:
```
score = model.evaluate(X_test, y_test, verbose=0)
print('Test loss:', score[0]) #Test loss: 0.0296396646054
print('Test accuracy:', score[1]) #Test accuracy: 0.9904
```

```
2022-11-01 14:40:55.253939: W tensorflow/core/framework/cpu_allocator_impl.cc:82] Allocation of 31360000 exceeds 10% of free system memory.
Test loss: 0.04956136643886566
Test accuracy: 0.9839000105857849
```