```
import numpy as np
import pandas as pd
import random
import tensorflow as tf
import matplotlib.pyplot as plt
#from matplotlib import pyplot as plt
from sklearn.metrics import accuracy_score

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
```

```
(X_train, y_train), (X_test, y_test) = mnist.load_data()
```

```
print(X_train.shape)
```

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

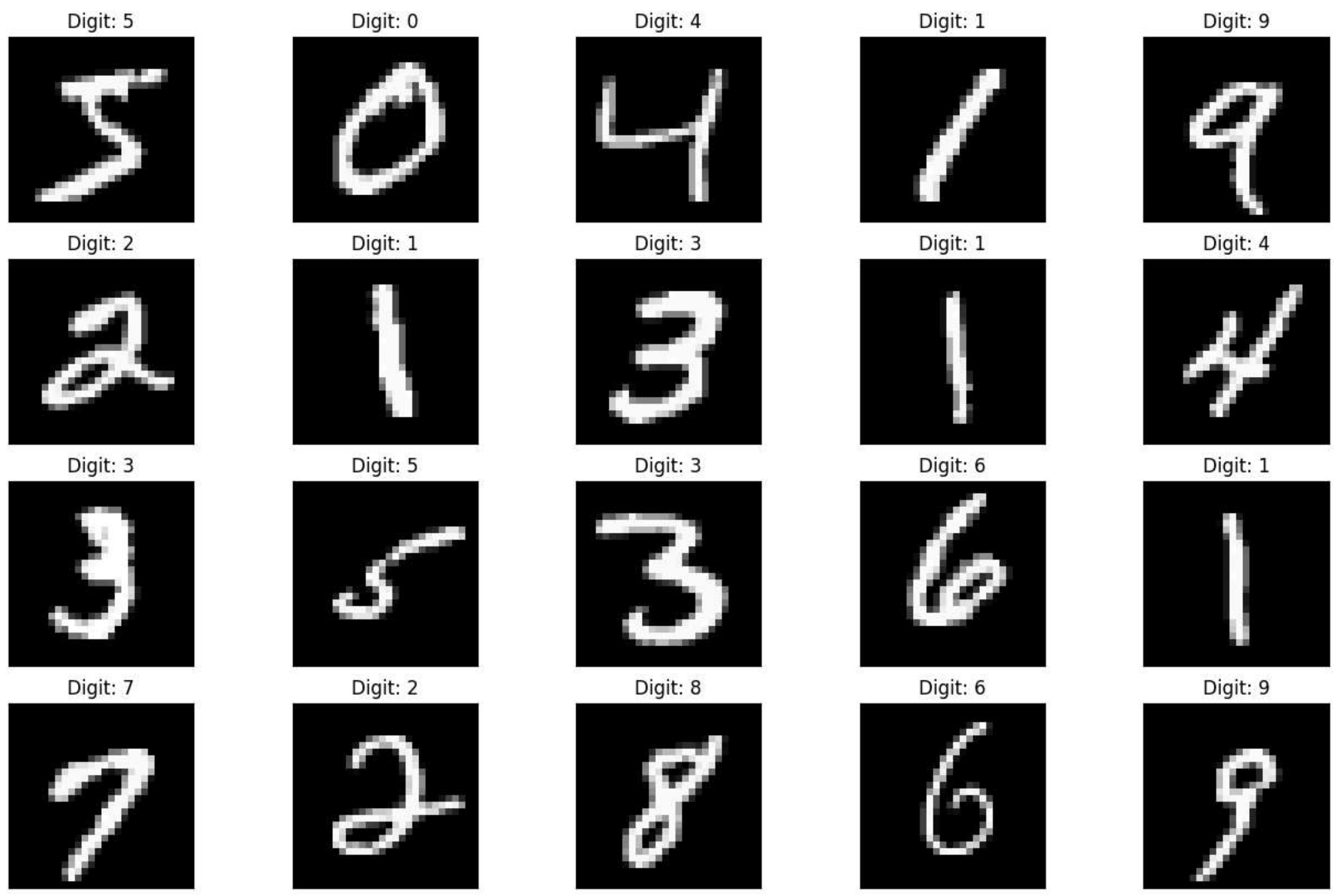
```
X_train[0].min(), X_train[0].max()
```

```
(0, 255)
```

```
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()
```

```
(0.0, 1.0)
```

```
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()
```



```
X_train = X_train.reshape((X_train.shape + (1,)))
X_test = X_test.reshape((X_test.shape + (1,)))
```

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

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

```
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")
])
```

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

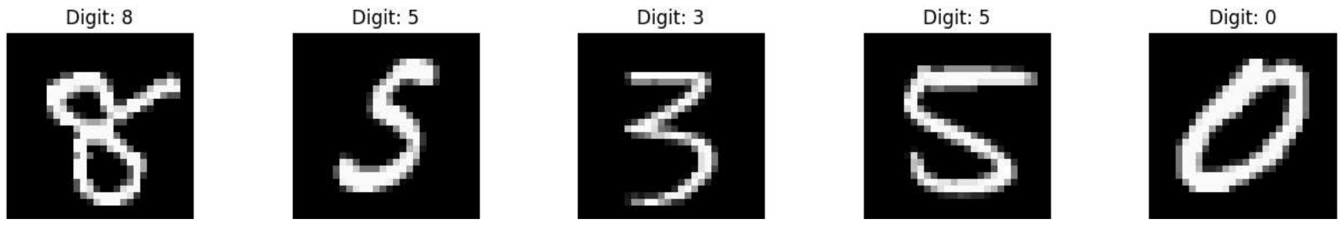
```
Model: "sequential_2"
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━┓
┃ Layer (type)                         ┃ Output Shape                 ┃         Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━┩
│ conv2d_2 (Conv2D)                    │ (None, 26, 26, 32)           │             320 │
├──────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ max_pooling2d_2 (MaxPooling2D)       │ (None, 13, 13, 32)           │               0 │
├──────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ flatten_2 (Flatten)                  │ (None, 5408)                 │               0 │
├──────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_4 (Dense)                      │ (None, 100)                  │         540,900 │
├──────────────────────────────────────┼──────────────────────────────┼─────────────────┤
│ dense_5 (Dense)                      │ (None, 10)                   │           1,010 │
└──────────────────────────────────────┴──────────────────────────────┴─────────────────┘
 Total params: 542,230 (2.07 MB)
 Trainable params: 542,230 (2.07 MB)
```

```
model.fit(X_train, y_train, epochs=10, batch_size=32)
```

```
Epoch 1/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 40s 21ms/step - accuracy: 0.8691 - loss: 0.4345
Epoch 2/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 38s 20ms/step - accuracy: 0.9732 - loss: 0.0868
Epoch 3/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 43s 21ms/step - accuracy: 0.9851 - loss: 0.0487
Epoch 4/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 38s 19ms/step - accuracy: 0.9895 - loss: 0.0341
Epoch 5/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 41s 19ms/step - accuracy: 0.9920 - loss: 0.0249
Epoch 6/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 36s 19ms/step - accuracy: 0.9946 - loss: 0.0184
Epoch 7/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 42s 20ms/step - accuracy: 0.9957 - loss: 0.0153
Epoch 8/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 41s 20ms/step - accuracy: 0.9979 - loss: 0.0099
Epoch 9/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 42s 21ms/step - accuracy: 0.9983 - loss: 0.0074
Epoch 10/10
1875/1875 ━━━━━━━━━━━━━━━━━━━━ 39s 20ms/step - accuracy: 0.9988 - loss: 0.0054
<keras.src.callbacks.history.History at 0x7d411ffa5840>
```

```
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 94ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 30ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 26ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 30ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 27ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 23ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 24ms/step
```



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

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 9ms/step
0.9867
```

```
n=random.randint(0,9999)
plt.imshow(X_test[n])
plt.show()
```