In [ ]:
```
#  Install required libraries (only run once in Jupyter)
!pip install tensorflow numpy matplotlib
```

```
Requirement already satisfied: tensorflow in c:\users\tadie\anaconda3\envs\py311_env\lib\site-packages (2.20.0)
Requirement already satisfied: numpy in c:\users\tadie\anaconda3\envs\py311_env\lib\site-packages (2.3.2)
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Requirement already satisfied: wheel<1.0,>=0.23.0 in c:\users\tadie\anaconda3\envs\py311_env\lib\site-packages (
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```

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Requirement already satisfied: MarkupSafe>=2.1.1 in c:\users\tadie\anaconda3\envs\py311_env\lib\site-packages (f
rom werkzeug>=1.0.1->tensorboard~=2.20.0->tensorflow) (3.0.2)
Requirement already satisfied: markdown-it-py>=2.2.0 in c:\users\tadie\anaconda3\envs\py311_env\lib\site-package
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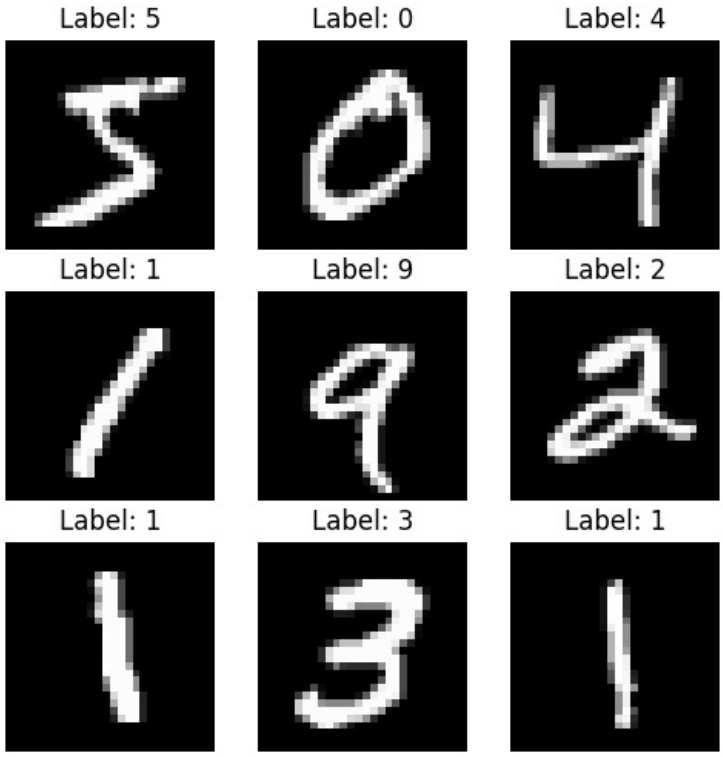
kdown-it-py>=2.2.0->rich->keras>=3.10.0->tensorflow) (0.1.2)
```

In [ ]:
```python
import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Flatten, Conv2D, MaxPooling2D
from tensorflow.keras.utils import to_categorical
```

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

# Show some images
plt.figure(figsize=(6,6))
for i in range(9):
    plt.subplot(3,3,i+1)
    plt.imshow(X_train[i], cmap="gray")
    plt.title(f"Label: {y_train[i]}")
    plt.axis("off")
plt.show()
```



In [ ]:
```python
# Reshape to [samples][width][height][channels]
X_train = X_train.reshape(X_train.shape[0], 28, 28, 1).astype("float32")
X_test = X_test.reshape(X_test.shape[0], 28, 28, 1).astype("float32")

# Normalize pixel values (0-255 → 0-1)
X_train = X_train / 255.0
X_test = X_test / 255.0

# One-hot encode labels
y_train = to_categorical(y_train, 10)
y_test = to_categorical(y_test, 10)
```

In [ ]:
```python
history = model.fit(
    X_train, y_train,
    validation_data=(X_test, y_test),
    epochs=10,
    batch_size=128,
    verbose=2
)
```

```
Epoch 1/10
469/469 - 34s - 72ms/step - accuracy: 0.8845 - loss: 0.3677 - val_accuracy: 0.9781 - val_loss: 0.0724
Epoch 2/10
469/469 - 33s - 70ms/step - accuracy: 0.9636 - loss: 0.1230 - val_accuracy: 0.9856 - val_loss: 0.0455
Epoch 3/10
469/469 - 32s - 68ms/step - accuracy: 0.9717 - loss: 0.0910 - val_accuracy: 0.9882 - val_loss: 0.0370
Epoch 4/10
469/469 - 27s - 58ms/step - accuracy: 0.9771 - loss: 0.0744 - val_accuracy: 0.9900 - val_loss: 0.0290
Epoch 5/10
469/469 - 32s - 69ms/step - accuracy: 0.9800 - loss: 0.0656 - val_accuracy: 0.9903 - val_loss: 0.0281
Epoch 6/10
469/469 - 34s - 73ms/step - accuracy: 0.9822 - loss: 0.0605 - val_accuracy: 0.9918 - val_loss: 0.0267
Epoch 7/10
469/469 - 41s - 88ms/step - accuracy: 0.9830 - loss: 0.0546 - val_accuracy: 0.9916 - val_loss: 0.0251
Epoch 8/10
469/469 - 31s - 67ms/step - accuracy: 0.9844 - loss: 0.0514 - val_accuracy: 0.9922 - val_loss: 0.0237
Epoch 9/10
469/469 - 30s - 64ms/step - accuracy: 0.9858 - loss: 0.0476 - val_accuracy: 0.9928 - val_loss: 0.0230
Epoch 10/10
469/469 - 34s - 73ms/step - accuracy: 0.9863 - loss: 0.0450 - val_accuracy: 0.9932 - val_loss: 0.0211
```

In [ ]:
```python
score = model.evaluate(X_test, y_test, verbose=0)
print(f"Test Loss: {score[0]:.4f}")
print(f"Test Accuracy: {score[1]*100:.2f}%")
```

```
Test Loss: 0.0211
Test Accuracy: 99.32%
```

In [ ]:
```python
plt.figure(figsize=(12,5))

# Accuracy
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label="Train Acc")
plt.plot(history.history['val_accuracy'], label="Val Acc")
plt.title("Model Accuracy")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.legend()

# Loss
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label="Train Loss")
plt.plot(history.history['val_loss'], label="Val Loss")
plt.title("Model Loss")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend()

plt.show()
```