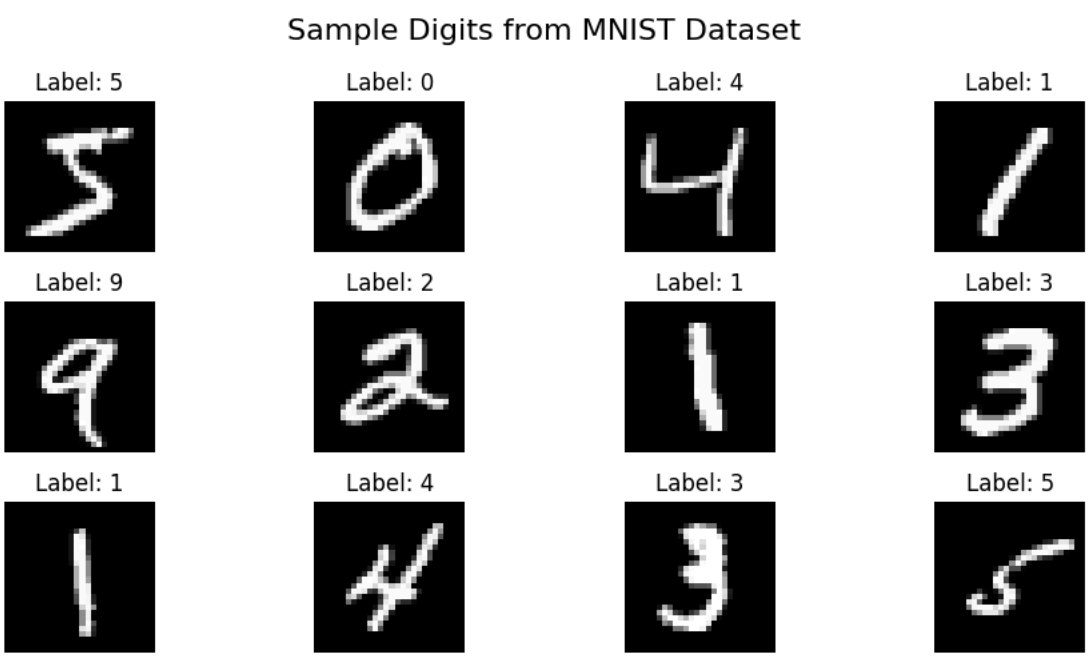
```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D
from tensorflow.keras.utils import to_categorical
from sklearn.metrics import classification_report, confusion_matrix


(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 ━━━━━━━━━━━━━━━━━━━━ 0s 0us/step
```

```
plt.figure(figsize=(10, 5))
for i in range(12):
    plt.subplot(3, 4, i + 1)
    plt.imshow(x_train[i], cmap='gray')
    plt.title(f"Label: {y_train[i]}")
    plt.axis('off')
plt.suptitle('Sample Digits from MNIST Dataset', fontsize=16)
plt.tight_layout()
plt.show()
```




```
x_train = x_train.reshape(-1, 28, 28, 1) / 255.0
x_test = x_test.reshape(-1, 28, 28, 1) / 255.0
y_train_cat = to_categorical(y_train, 10)
y_test_cat = to_categorical(y_test, 10)
```

```
model = Sequential([
    Conv2D(32, kernel_size=(3,3), activation='relu', input_shape=(28,28,1)),
    MaxPooling2D(pool_size=(2,2)),
    Conv2D(64, kernel_size=(3,3), activation='relu'),
    MaxPooling2D(pool_size=(2,2)),
    Flatten(),
    Dense(128, activation='relu'),
    Dense(10, activation='softmax')
])
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`inpu
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
# 5. Compile and train
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
history = model.fit(x_train, y_train_cat, epochs=5, validation_split=0.2)
```

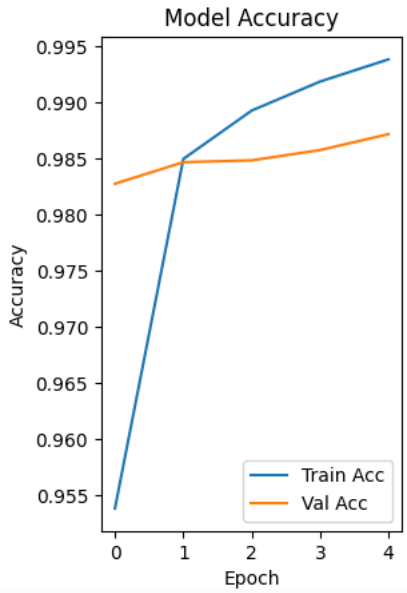
```
Epoch 1/5
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 58s 37ms/step - accuracy: 0.8968 - loss: 0.3389 - val_accuracy: 0.9827 - val_loss: 0.0576
Epoch 2/5
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 95s 46ms/step - accuracy: 0.9836 - loss: 0.0507 - val_accuracy: 0.9847 - val_loss: 0.0509
Epoch 3/5
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 66s 35ms/step - accuracy: 0.9894 - loss: 0.0317 - val_accuracy: 0.9848 - val_loss: 0.0535
Epoch 4/5
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 81s 35ms/step - accuracy: 0.9921 - loss: 0.0222 - val_accuracy: 0.9858 - val_loss: 0.0498
Epoch 5/5
1500/1500 ━━━━━━━━━━━━━━━━━━━━ 83s 35ms/step - accuracy: 0.9946 - loss: 0.0150 - val_accuracy: 0.9872 - val_loss: 0.0451
```

```
plt.figure(figsize=(12, 5))
```

```
<Figure size 1200x500 with 0 Axes>
```

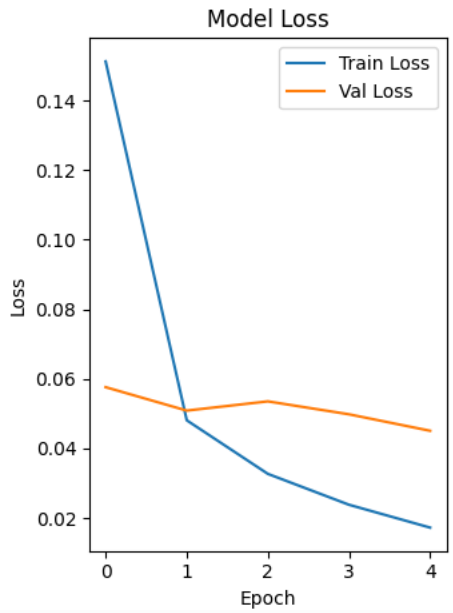
```
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.title('Model Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
```

```
<matplotlib.legend.Legend at 0x7bd7ac3c9b90>
```




```
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.tight_layout()
plt.show()
```




```
test_loss, test_acc = model.evaluate(x_test, y_test_cat)
print(f"\nTest Accuracy: {test_acc:.4f}")
```

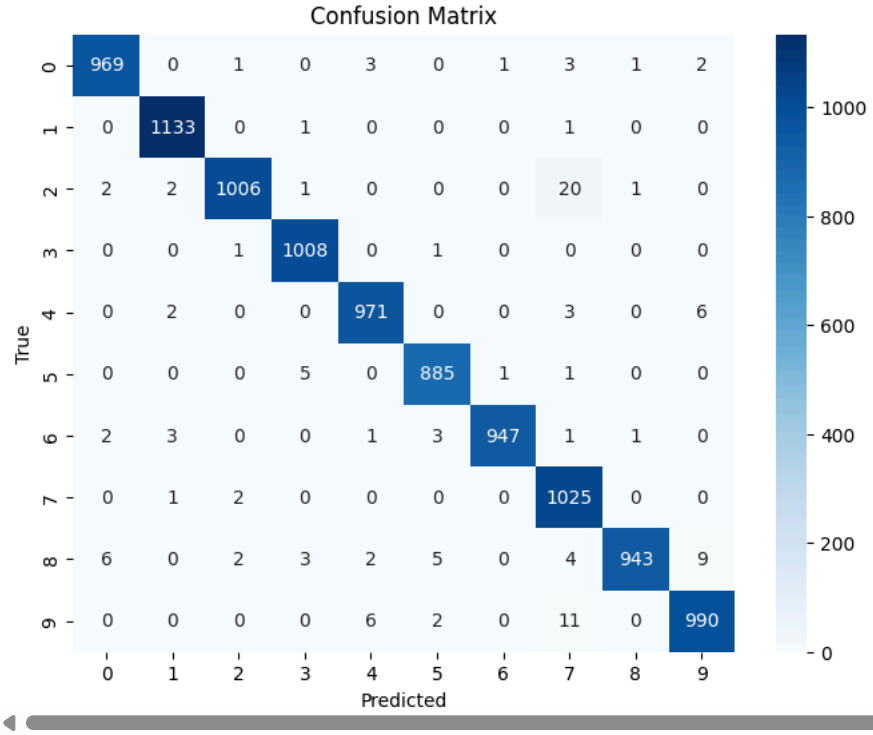
```
313/313 ━━━━━━━━━━━━━━━━━━━━ 4s 12ms/step - accuracy: 0.9853 - loss: 0.0501

Test Accuracy: 0.9877
```

```
y_pred = model.predict(x_test).argmax(axis=1)
cm = confusion_matrix(y_test, y_pred)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 10ms/step
```

```
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=range(10), yticklabels=range(10))
plt.title('Confusion Matrix')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.show()
```



```
print("\nClassification Report:")
print(classification_report(y_test, y_pred))
```

```
Classification Report:
              precision    recall  f1-score   support

           0       0.99      0.99      0.99       980
           1       0.99      1.00      1.00      1135
           2       0.99      0.97      0.98      1032
           3       0.99      1.00      0.99      1010
           4       0.99      0.99      0.99       982
           5       0.99      0.99      0.99       892
           6       1.00      0.99      0.99       958
           7       0.96      1.00      0.98      1028
           8       1.00      0.97      0.98       974
           9       0.98      0.98      0.98      1009

    accuracy                           0.99     10000
   macro avg       0.99      0.99      0.99     10000
weighted avg       0.99      0.99      0.99     10000
```

```
plt.figure(figsize=(10, 5))
for i in range(10):
    plt.subplot(2, 5, i + 1)
    plt.imshow(x_test[i].reshape(28, 28), cmap='gray')
    plt.title(f"True: {y_test[i]}\nPred: {y_pred[i]}")
    plt.axis('off')
plt.tight_layout()
plt.suptitle("Predictions on Test Images", fontsize=16)
plt.show()
```