In [1]:
```
#Import necessary libraries
import tensorflow as tf
from tensorflow.keras import layers, models
import matplotlib.pyplot as plt
from tensorflow.keras.datasets import mnist
```

In [2]:
```
#Load the MNIST dataset
(x_train, y_train), (x_test, y_test) = mnist.load_data()
print("Training data shape:", x_train.shape)
print("Test data shape:", x_test.shape)
```

```
Training data shape: (60000, 28, 28)
Test data shape: (10000, 28, 28)
```

In [3]:
```
#Normalize the pixel values between 0 and 1
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0
```

In [4]:
```
x_train
```

Out[4]:
```
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., 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=float32)
```

In [5]:
```
x_test
```

Out[5]:
```
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., 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=float32)
```

In [6]:
```
#Reshape data to fit the model (28x28x1)
x_train = x_train.reshape((x_train.shape[0], 28, 28, 1))
x_test = x_test.reshape((x_test.shape[0], 28, 28, 1))
```

In [7]:
```
x_train
```

```
          [0.]]],


        [[[0.],
          [0.],
          [0.],
          ...,
          [0.],
          [0.],
          [0.]],

         [[0.],
          [0.],
          [0.],
          ...,
          [0.],
          [0.],
          [0.]],

         [[0.],
```

In [8]:
```
x_test
```

```
         [[0.],
          [0.],
          [0.],
          ...,
          [0.],
          [0.],
          [0.]]],


        [[[0.],
          [0.],
          [0.],
          ...,
          [0.],
          [0.],
          [0.]],

         [[0.],
          [0.],
```

In [9]:
```
#Convert labels to one-hot encoding
y_train = tf.keras.utils.to_categorical(y_train, 10)
y_test = tf.keras.utils.to_categorical(y_test, 10)
```

In [10]:
```
y_train
```

Out[10]:
```
array([[0., 0., 0., ..., 0., 0., 0.],
       [1., 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., 1., 0.]])
```

In [11]:
```
y_test
```

Out[11]:
```
array([[0., 0., 0., ..., 1., 0., 0.],
       [0., 0., 1., ..., 0., 0., 0.],
       [0., 1., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

In [13]:
```
#Build a CNN model using Input layer
#Include MaxPooling layers
model = models.Sequential()
model.add(layers.Input(shape=(28, 28, 1)))  # Specify the input shape here
model.add(layers.Conv2D(32, (3, 3), activation='relu'))
model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(64, (3, 3), activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))
```

In [14]:
```
#Add Dense layers and output layer
model.add(layers.Flatten())
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```

In [15]:
```
#Compile the model
#Use the 'adam' optimizer.
#Set the loss function to 'categorical_crossentropy'.
#Track accuracy as the metric
model.compile(optimizer='adam',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

In [16]:

```
#Train the model
history = model.fit(x_train, y_train, epochs=10, batch_size=64, validatior
```

```
Epoch 1/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 168s 193ms/step - accuracy: 0.8734 - loss: 0.4090 - val_accuracy: 0.9821 - val_loss: 0.0588
Epoch 2/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 164s 142ms/step - accuracy: 0.9836 - loss: 0.0523 - val_accuracy: 0.9858 - val_loss: 0.0480
Epoch 3/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 144s 145ms/step - accuracy: 0.9903 - loss: 0.0328 - val_accuracy: 0.9898 - val_loss: 0.0363
Epoch 4/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 127s 124ms/step - accuracy: 0.9922 - loss: 0.0224 - val_accuracy: 0.9877 - val_loss: 0.0428
Epoch 5/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 103s 137ms/step - accuracy: 0.9942 - loss: 0.0177 - val_accuracy: 0.9867 - val_loss: 0.0430
Epoch 6/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 102s 137ms/step - accuracy: 0.9957 - loss: 0.0131 - val_accuracy: 0.9904 - val_loss: 0.0405
Epoch 7/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 99s 132ms/step - accuracy: 0.9957 - loss: 0.0128 - val_accuracy: 0.9908 - val_loss: 0.0361
Epoch 8/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 145s 136ms/step - accuracy: 0.9975 - loss: 0.0084 - val_accuracy: 0.9902 - val_loss: 0.0400
Epoch 9/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 154s 152ms/step - accuracy: 0.9972 - loss: 0.0075 - val_accuracy: 0.9922 - val_loss: 0.0335
Epoch 10/10
750/750 ━━━━━━━━━━━━━━━━━━━━ 62s 83ms/step - accuracy: 0.9980 - loss: 0.0058 - val_accuracy: 0.9910 - val_loss: 0.0371
```

In [17]:

```
#Evaluate the model on test data
test_loss, test_acc = model.evaluate(x_test, y_test)
print("Test accuracy:", test_acc)
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 10ms/step - accuracy: 0.9888 - loss: 0.0424
Test accuracy: 0.9908999800682068
```

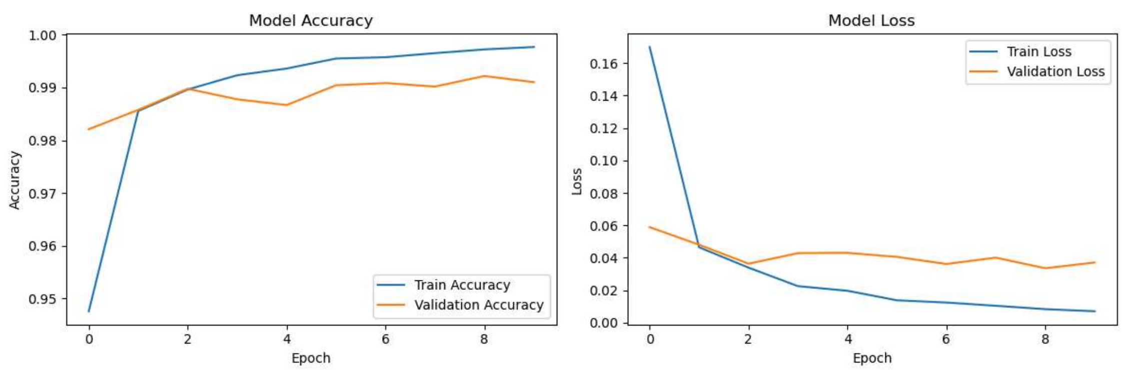
In [19]:

```
# Plot accuracy and loss graphs
plt.figure(figsize=(12, 4))

# Plot training & validation accuracy values
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.title('Model Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()

# Plot training & validation loss values
plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title('Model Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()

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



In [ ]: