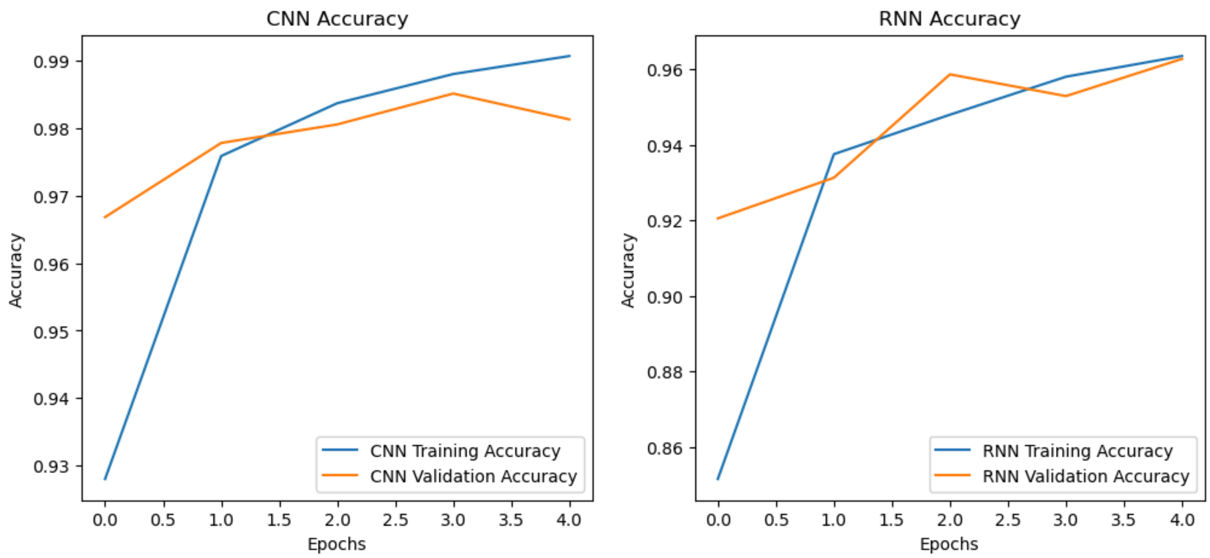
In [1]:
```
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Si
from tensorflow.keras.datasets import mnist
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt

# Load the MNIST dataset
(x_train, y_train), (x_test, y_test) = mnist.load_data()

# Normalize the data
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0

# Reshape data for CNN (28x28x1) and RNN (28 timesteps, 28 features)
x_train_cnn = x_train.reshape(-1, 28, 28, 1)
x_test_cnn = x_test.reshape(-1, 28, 28, 1)
x_train_rnn = x_train.reshape(-1, 28, 28)
x_test_rnn = x_test.reshape(-1, 28, 28)

# Split the data into train and validation sets
x_train_cnn, x_val_cnn, y_train_cnn, y_val_cnn = train_test_split(x_train_cn
x_train_rnn, x_val_rnn, y_train_rnn, y_val_rnn = train_test_split(x_train_rn

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

cnn_model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',
cnn_history = cnn_model.fit(x_train_cnn, y_train_cnn, validation_data=(x_val

# RNN model
rnn_model = Sequential([
    SimpleRNN(128, input_shape=(28, 28)),
    Dense(10, activation='softmax')
])

rnn_model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',
rnn_history = rnn_model.fit(x_train_rnn, y_train_rnn, validation_data=(x_val

# Evaluate both models on the test set
cnn_test_loss, cnn_test_acc = cnn_model.evaluate(x_test_cnn, y_test)
rnn_test_loss, rnn_test_acc = rnn_model.evaluate(x_test_rnn, y_test)

# Print the results
print(f"CNN Test Accuracy: {cnn_test_acc}")
print(f"RNN Test Accuracy: {rnn_test_acc}")
```

```python
# Plot the training history
plt.figure(figsize=(12, 5))

plt.subplot(1, 2, 1)
plt.plot(cnn_history.history['accuracy'], label='CNN Training Accuracy')
plt.plot(cnn_history.history['val_accuracy'], label='CNN Validation Accuracy
plt.title('CNN Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(rnn_history.history['accuracy'], label='RNN Training Accuracy')
plt.plot(rnn_history.history['val_accuracy'], label='RNN Validation Accuracy
plt.title('RNN Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.show()
```

```
Epoch 1/5
D:\anaconda\Lib\site-packages\keras\src\layers\convolutional\base_conv.py:10
7: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a laye
r. When using Sequential models, prefer using an `Input(shape)` object as th
e first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
375/375 ━━━━━━━━━━━━━━━━━━━━ 9s 20ms/step - accuracy: 0.8701 - loss: 0.4752
- val_accuracy: 0.9668 - val_loss: 0.1112
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 8s 22ms/step - accuracy: 0.9741 - loss: 0.0882
- val_accuracy: 0.9778 - val_loss: 0.0761
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 7s 20ms/step - accuracy: 0.9833 - loss: 0.0550
- val_accuracy: 0.9806 - val_loss: 0.0629
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 8s 22ms/step - accuracy: 0.9884 - loss: 0.0392
- val_accuracy: 0.9852 - val_loss: 0.0520
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 7s 20ms/step - accuracy: 0.9914 - loss: 0.0291
- val_accuracy: 0.9813 - val_loss: 0.0618
Epoch 1/5
D:\anaconda\Lib\site-packages\keras\src\layers\rnn\rnn.py:204: UserWarning:
Do not pass an `input_shape`/`input_dim` argument to a layer. When using Seq
uential models, prefer using an `Input(shape)` object as the first layer in
the model instead.
  super().__init__(**kwargs)
```

```
375/375 ━━━━━━━━━━━━━━━━━━━━ 6s 11ms/step - accuracy: 0.7466 - loss: 0.8400
- val_accuracy: 0.9205 - val_loss: 0.2797
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 4s 11ms/step - accuracy: 0.9309 - loss: 0.2440
- val_accuracy: 0.9312 - val_loss: 0.2345
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 6s 15ms/step - accuracy: 0.9447 - loss: 0.1893
- val_accuracy: 0.9586 - val_loss: 0.1546
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 4s 11ms/step - accuracy: 0.9586 - loss: 0.1429
- val_accuracy: 0.9528 - val_loss: 0.1602
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 4s 10ms/step - accuracy: 0.9613 - loss: 0.1345
- val_accuracy: 0.9627 - val_loss: 0.1336
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step - accuracy: 0.9776 - loss: 0.0666
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 3ms/step - accuracy: 0.9559 - loss: 0.1555
CNN Test Accuracy: 0.9817000031471252
RNN Test Accuracy: 0.9595999717712402
```



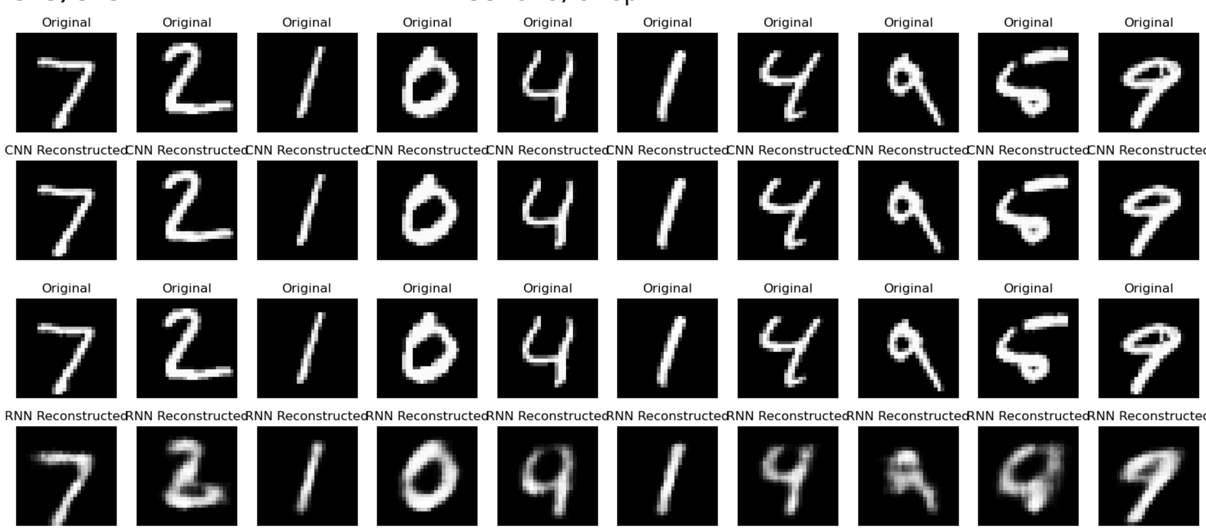
In [2]:

```
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Up
from tensorflow.keras.datasets import mnist
import matplotlib.pyplot as plt

# Load the MNIST dataset
(x_train, _), (x_test, _) = mnist.load_data()

# Normalize the data
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0

# Reshape data for CNN (28x28x1) and RNN (28 timesteps, 28 features)
x_train_cnn = x_train.reshape(-1, 28, 28, 1)
x_test_cnn = x_test.reshape(-1, 28, 28, 1)
x_train_rnn = x_train.reshape(-1, 28, 28)
x_test_rnn = x_test.reshape(-1, 28, 28)
```

```
# CNN autoencoder model
cnn_autoencoder = Sequential([
    # Encoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same', input_
    MaxPooling2D(pool_size=(2, 2), padding='same'),
    # Decoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same'),
    UpSampling2D(size=(2, 2)),
    Conv2D(1, kernel_size=(3, 3), activation='sigmoid', padding='same')
])

cnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
cnn_autoencoder.fit(x_train_cnn, x_train_cnn, epochs=5, batch_size=128, vali

# RNN autoencoder model
rnn_autoencoder = Sequential([
    # Encoder
    SimpleRNN(128, activation='relu', input_shape=(28, 28), return_sequences
    RepeatVector(28),
    # Decoder
    SimpleRNN(128, activation='relu', return_sequences=True),
    TimeDistributed(Dense(28, activation='sigmoid'))
])

rnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
rnn_autoencoder.fit(x_train_rnn, x_train_rnn, epochs=5, batch_size=128, vali

# Reconstruct images using both models
cnn_reconstructed = cnn_autoencoder.predict(x_test_cnn)
rnn_reconstructed = rnn_autoencoder.predict(x_test_rnn)

# Plot original and reconstructed images
n = 10  # number of images to display
plt.figure(figsize=(20, 4))
for i in range(n):
    # Display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i], cmap='gray')
    plt.title("Original")
    plt.axis('off')

    # Display CNN reconstructed
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(cnn_reconstructed[i].reshape(28, 28), cmap='gray')
    plt.title("CNN Reconstructed")
    plt.axis('off')

plt.figure(figsize=(20, 4))
for i in range(n):
    # Display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i], cmap='gray')
    plt.title("Original")
    plt.axis('off')

    # Display RNN reconstructed
```

```python
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(rnn_reconstructed[i].reshape(28, 28), cmap='gray')
    plt.title("RNN Reconstructed")
    plt.axis('off')

plt.show()
```

```
Epoch 1/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 33ms/step - loss: 0.2324 - val_loss: 0.0673
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 13s 35ms/step - loss: 0.0661 - val_loss: 0.0650
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 38ms/step - loss: 0.0645 - val_loss: 0.0641
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 17s 46ms/step - loss: 0.0634 - val_loss: 0.0635
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 15s 40ms/step - loss: 0.0628 - val_loss: 0.0631
Epoch 1/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 23s 42ms/step - loss: 0.3235 - val_loss: 0.2001
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 15s 41ms/step - loss: 0.1892 - val_loss: 0.1670
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 38ms/step - loss: 0.1625 - val_loss: 0.1518
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 15s 39ms/step - loss: 0.1476 - val_loss: 0.1418
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 37ms/step - loss: 0.1398 - val_loss: 0.1341
313/313 ━━━━━━━━━━━━━━━━━━━━ 2s 5ms/step
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 8ms/step
```



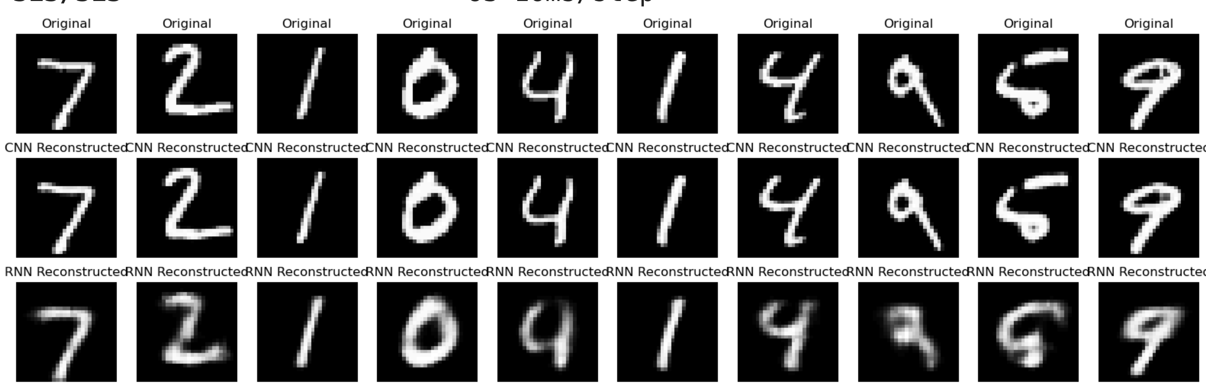
In [3]:

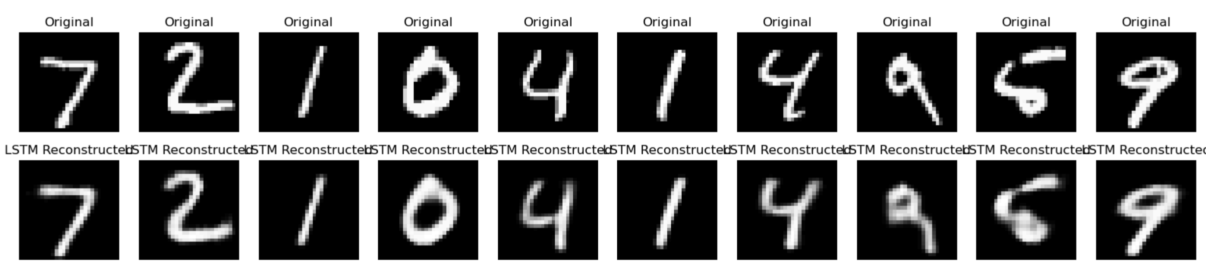
```python
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Up
from tensorflow.keras.datasets import mnist
import matplotlib.pyplot as plt

# Load the MNIST dataset
(x_train, _), (x_test, _) = mnist.load_data()

# Normalize the data
```

```python
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0

# Reshape data for CNN (28x28x1), RNN and LSTM (28 timesteps, 28 features)
x_train_cnn = x_train.reshape(-1, 28, 28, 1)
x_test_cnn = x_test.reshape(-1, 28, 28, 1)
x_train_rnn = x_train.reshape(-1, 28, 28)
x_test_rnn = x_test.reshape(-1, 28, 28)

# CNN autoencoder model
cnn_autoencoder = Sequential([
    # Encoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same', input_
    MaxPooling2D(pool_size=(2, 2), padding='same'),
    # Decoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same'),
    UpSampling2D(size=(2, 2)),
    Conv2D(1, kernel_size=(3, 3), activation='sigmoid', padding='same')
])

cnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
cnn_autoencoder.fit(x_train_cnn, x_train_cnn, epochs=5, batch_size=128, vali

# RNN autoencoder model
rnn_autoencoder = Sequential([
    # Encoder
    SimpleRNN(128, activation='relu', input_shape=(28, 28), return_sequences
    RepeatVector(28),
    # Decoder
    SimpleRNN(128, activation='relu', return_sequences=True),
    TimeDistributed(Dense(28, activation='sigmoid'))
])

rnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
rnn_autoencoder.fit(x_train_rnn, x_train_rnn, epochs=5, batch_size=128, vali

# LSTM autoencoder model
lstm_autoencoder = Sequential([
    # Encoder
    LSTM(128, activation='relu', input_shape=(28, 28), return_sequences=Fals
    RepeatVector(28),
    # Decoder
    LSTM(128, activation='relu', return_sequences=True),
    TimeDistributed(Dense(28, activation='sigmoid'))
])

lstm_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
lstm_autoencoder.fit(x_train_rnn, x_train_rnn, epochs=5, batch_size=128, val

# Reconstruct images using all models
cnn_reconstructed = cnn_autoencoder.predict(x_test_cnn)
rnn_reconstructed = rnn_autoencoder.predict(x_test_rnn)
lstm_reconstructed = lstm_autoencoder.predict(x_test_rnn)

# Plot original and reconstructed images
n = 10  # number of images to display
```

```python
plt.figure(figsize=(20, 6))

for i in range(n):
    # Display original
    ax = plt.subplot(3, n, i + 1)
    plt.imshow(x_test[i], cmap='gray')
    plt.title("Original")
    plt.axis('off')

    # Display CNN reconstructed
    ax = plt.subplot(3, n, i + 1 + n)
    plt.imshow(cnn_reconstructed[i].reshape(28, 28), cmap='gray')
    plt.title("CNN Reconstructed")
    plt.axis('off')

    # Display RNN reconstructed
    ax = plt.subplot(3, n, i + 1 + 2 * n)
    plt.imshow(rnn_reconstructed[i].reshape(28, 28), cmap='gray')
    plt.title("RNN Reconstructed")
    plt.axis('off')

plt.figure(figsize=(20, 4))
for i in range(n):
    # Display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i], cmap='gray')
    plt.title("Original")
    plt.axis('off')

    # Display LSTM reconstructed
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(lstm_reconstructed[i].reshape(28, 28), cmap='gray')
    plt.title("LSTM Reconstructed")
    plt.axis('off')

plt.show()
```

```
Epoch 1/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 35ms/step - loss: 0.2273 - val_loss: 0.0670
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 13s 35ms/step - loss: 0.0659 - val_loss: 0.0650
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 15s 40ms/step - loss: 0.0643 - val_loss: 0.0642
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 38ms/step - loss: 0.0635 - val_loss: 0.0636
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 15s 39ms/step - loss: 0.0630 - val_loss: 0.0632
Epoch 1/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 23s 45ms/step - loss: 0.3144 - val_loss: 0.2045
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 19s 50ms/step - loss: 0.1922 - val_loss: 0.1662
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 37ms/step - loss: 0.1615 - val_loss: 0.1492
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 14s 37ms/step - loss: 0.1471 - val_loss: 0.1394
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 13s 36ms/step - loss: 0.1380 - val_loss: 0.1328
Epoch 1/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 46s 103ms/step - loss: 0.3271 - val_loss: 0.186
3
Epoch 2/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 37s 98ms/step - loss: 0.1758 - val_loss: 0.1434
Epoch 3/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 41s 110ms/step - loss: 0.1367 - val_loss: 0.122
4
Epoch 4/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 2060s 6s/step - loss: 0.1205 - val_loss: 0.1128
Epoch 5/5
375/375 ━━━━━━━━━━━━━━━━━━━━ 41s 108ms/step - loss: 0.1104 - val_loss: 0.105
2
313/313 ━━━━━━━━━━━━━━━━━━━━ 2s 6ms/step
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 8ms/step
313/313 ━━━━━━━━━━━━━━━━━━━━ 6s 16ms/step
```





In [4]:
```python
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Up
from tensorflow.keras.datasets import mnist
import matplotlib.pyplot as plt

# Load and preprocess the MNIST dataset
(x_train, _), (x_test, _) = mnist.load_data()
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0
x_train_cnn = x_train.reshape(-1, 28, 28, 1)
x_test_cnn = x_test.reshape(-1, 28, 28, 1)
x_train_rnn = x_train.reshape(-1, 28, 28)
x_test_rnn = x_test.reshape(-1, 28, 28)

# Define CNN autoencoder model
cnn_autoencoder = Sequential([
    # Encoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same', input_
    MaxPooling2D(pool_size=(2, 2), padding='same'),
    # Decoder
    Conv2D(32, kernel_size=(3, 3), activation='relu', padding='same'),
    UpSampling2D(size=(2, 2)),
    Conv2D(1, kernel_size=(3, 3), activation='sigmoid', padding='same')
])

# Define RNN autoencoder model
rnn_autoencoder = Sequential([
    # Encoder
    SimpleRNN(128, activation='relu', input_shape=(28, 28), return_sequences
    RepeatVector(28),
    # Decoder
    SimpleRNN(128, activation='relu', return_sequences=True),
    TimeDistributed(Dense(28, activation='sigmoid'))
])

# Define LSTM autoencoder model
lstm_autoencoder = Sequential([
    # Encoder
    LSTM(128, activation='relu', input_shape=(28, 28), return_sequences=Fals
    RepeatVector(28),
    # Decoder
    LSTM(128, activation='relu', return_sequences=True),
    TimeDistributed(Dense(28, activation='sigmoid'))
])

# Compile models (no need to fit to display summaries)
cnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
rnn_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
lstm_autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

# Print summaries of the models
print("CNN Autoencoder Summary:")
cnn_autoencoder.summary()
```

```python
print("\nRNN Autoencoder Summary:")
rnn_autoencoder.summary()

print("\nLSTM Autoencoder Summary:")
lstm_autoencoder.summary()
```

CNN Autoencoder Summary:
Model: "sequential_7"

Layer (type)	Output Shape	Par
conv2d_7 (Conv2D)	(None, 28, 28, 32)	
max_pooling2d_3 (MaxPooling2D)	(None, 14, 14, 32)	
conv2d_8 (Conv2D)	(None, 14, 14, 32)	9
up_sampling2d_2 (UpSampling2D)	(None, 28, 28, 32)	
conv2d_9 (Conv2D)	(None, 28, 28, 1)	

Total params: 9,857 (38.50 KB)

Trainable params: 9,857 (38.50 KB)

Non-trainable params: 0 (0.00 B)

RNN Autoencoder Summary:
Model: "sequential_8"

Layer (type)	Output Shape	Par
simple_rnn_5 (SimpleRNN)	(None, 128)	20
repeat_vector_3 (RepeatVector)	(None, 28, 128)	
simple_rnn_6 (SimpleRNN)	(None, 28, 128)	32
time_distributed_3 (TimeDistributed)	(None, 28, 28)	3

Total params: 56,604 (221.11 KB)

Trainable params: 56,604 (221.11 KB)

Non-trainable params: 0 (0.00 B)

LSTM Autoencoder Summary:
Model: "sequential_9"

Layer (type)	Output Shape	Par
lstm_2 (LSTM)	(None, 128)	80
repeat_vector_4 (RepeatVector)	(None, 28, 128)	
lstm_3 (LSTM)	(None, 28, 128)	131
time_distributed_4 (TimeDistributed)	(None, 28, 28)	3

Total params: 215,580 (842.11 KB)

Trainable params: 215,580 (842.11 KB)

Non-trainable params: 0 (0.00 B)

In [ ]: