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1.0.1 Load the MNIST Dataset

1. Import the MNIST dataset using TensorFlow/Keras.
2. Normalize the pixel values to the range [0, 1].

```
[2]: from tensorflow.keras.datasets import mnist
import numpy as np
# Load the MNIST dataset
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

```
[ ]: # Normalize
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0
```

```
[ ]: # Add a channel dimension to make it compatible with CNN layers
x_train = np.expand_dims(x_train, axis=-1)
x_test = np.expand_dims(x_test, axis=-1)
```

```
[6]: print("Training data shape: ", x_train.shape)
print("Training data shape: ", x_train.shape)
```

Training data shape: (60000, 28, 28, 1)
Training data shape: (60000, 28, 28, 1)

1.0.2 2. Add Noise to the Dataset

1. Introduce Gaussian noise to the MNIST dataset.
2. Ensure the noisy pixel values remain in the range [0, 1] using np.clip()

```
[7]: noise_factor = 0.5
x_train_noisy = x_train + noise_factor * np.random.normal(loc=0.0, scale=1.0,
size=x_train.shape)
x_test_noisy = x_test + noise_factor * np.random.normal(loc=0.0, scale=1.0,
size=x_test.shape)
```

```
[8]: # Clip pixel values to be in [0, 1]
x_train_noisy = np.clip(x_train_noisy, 0., 1.)
```

```
x_test_noisy = np.clip(x_test_noisy, 0., 1.)
```

```
[9]: print("Noisy training data shape:", x_train_noisy.shape)
```

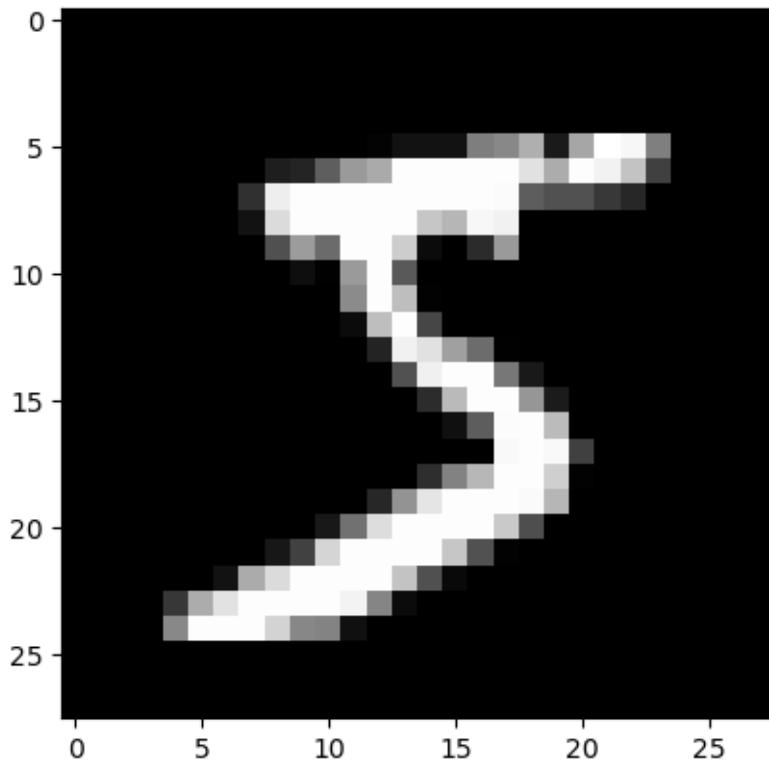
Noisy training data shape: (60000, 28, 28, 1)

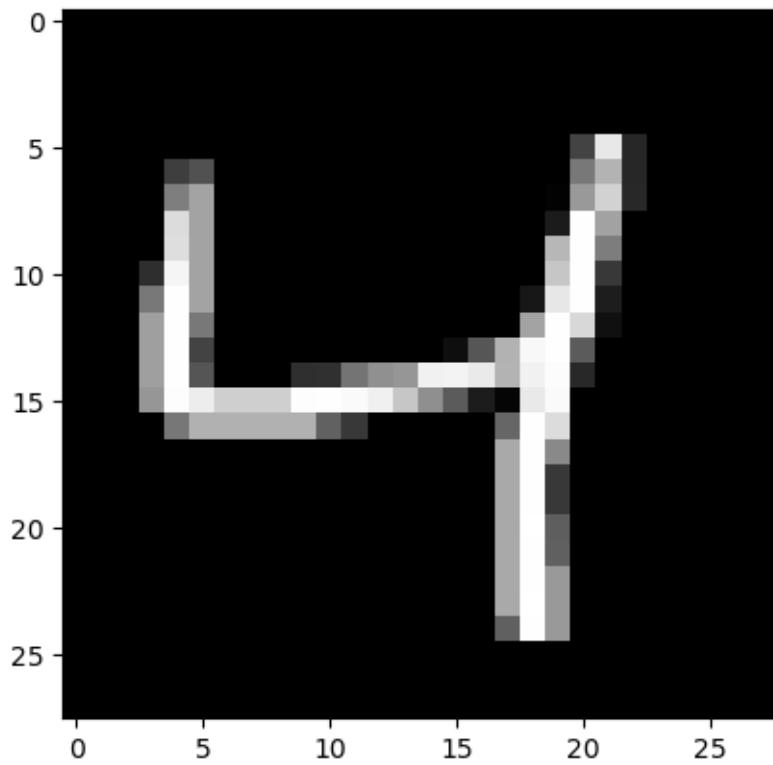
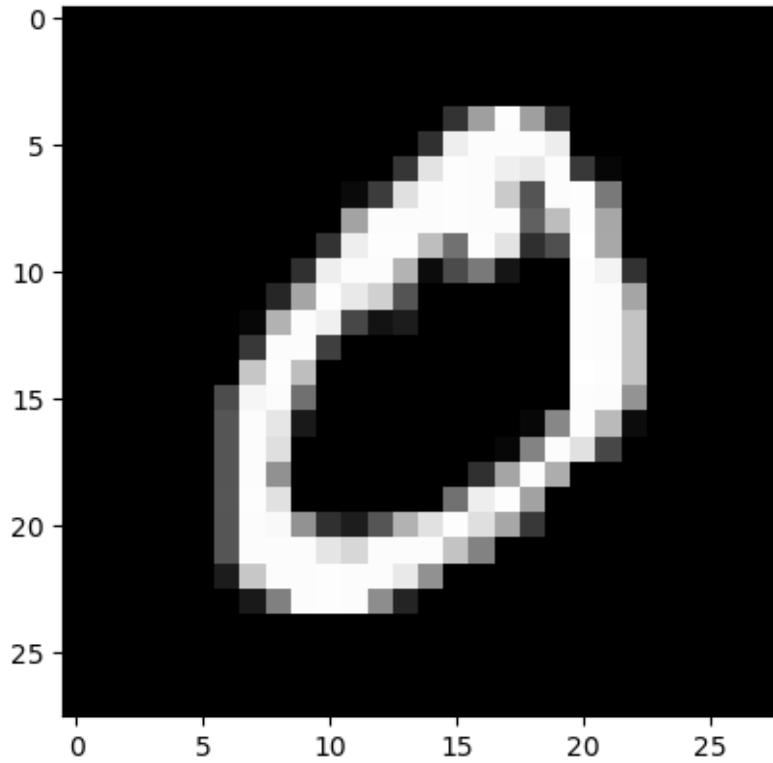
1.0.3 3. Visualize the Dataset

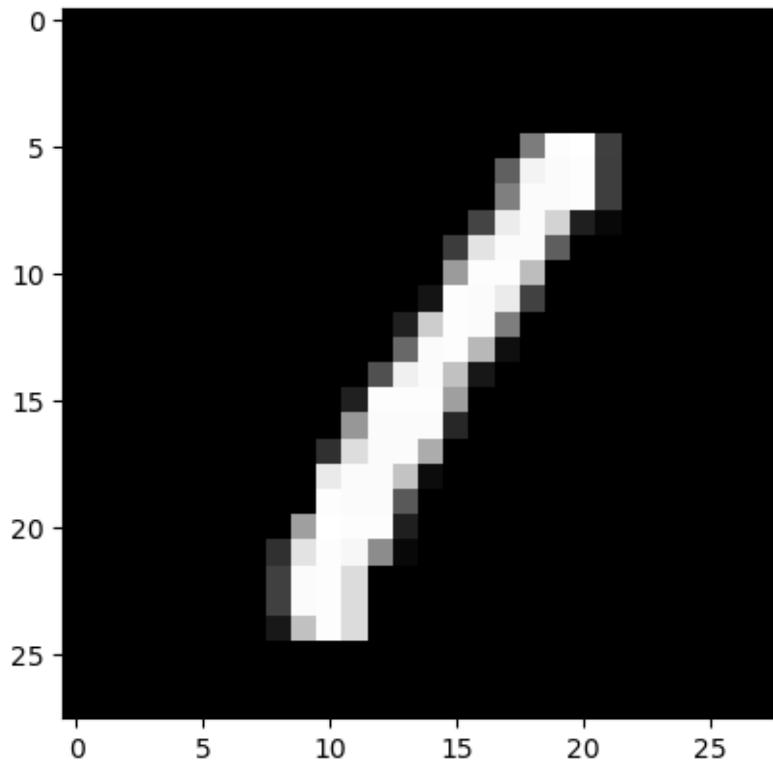
Plot a few examples of the original and noisy images.

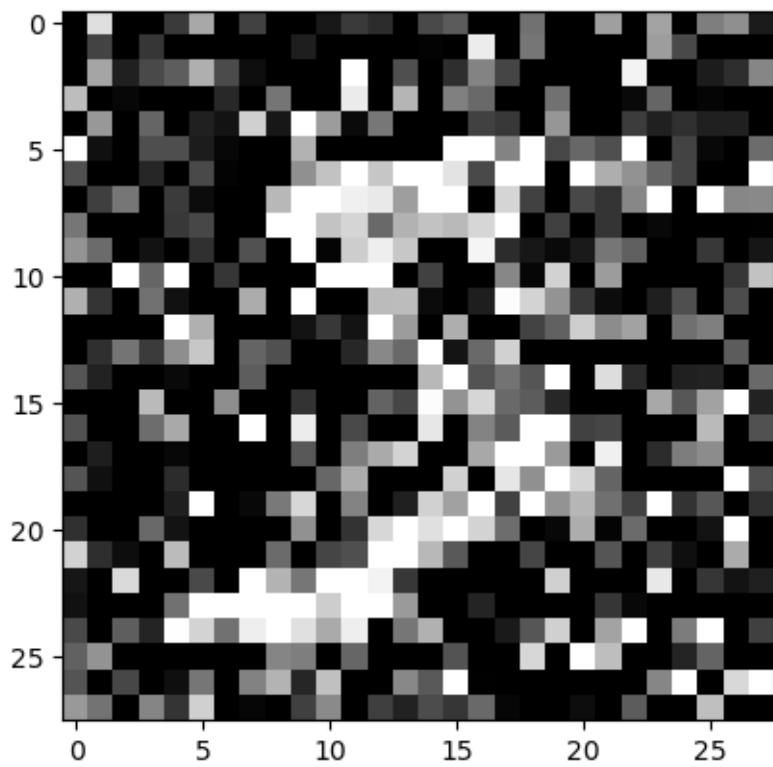
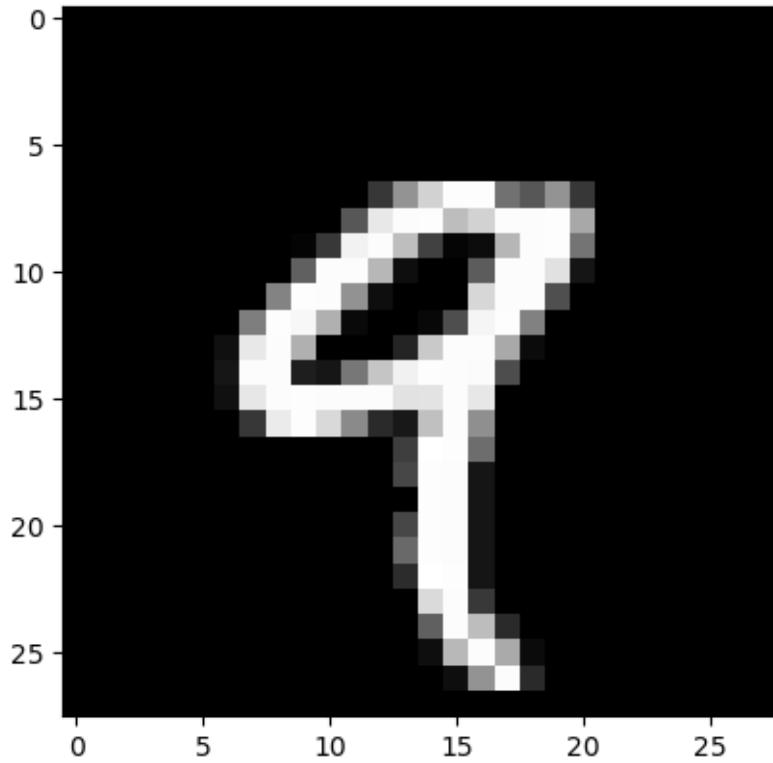
```
[13]: import matplotlib.pyplot as plt

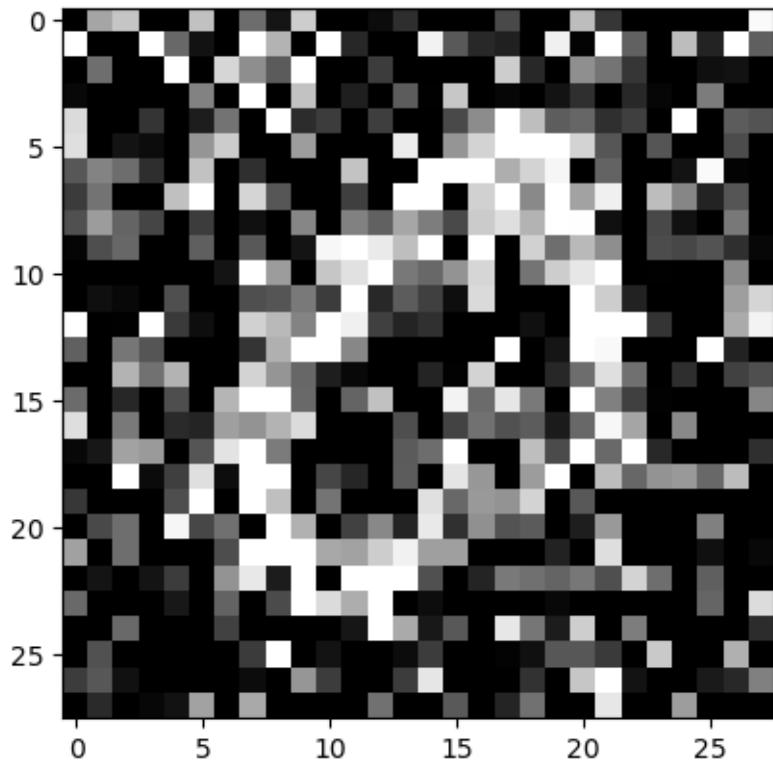
for i in range(0, 5):
    plt.imshow(x_train[i], cmap='gray')
    plt.show()
for i in range(0, 5):
    plt.imshow(x_train_noisy[i], cmap='gray')
    plt.show()
```

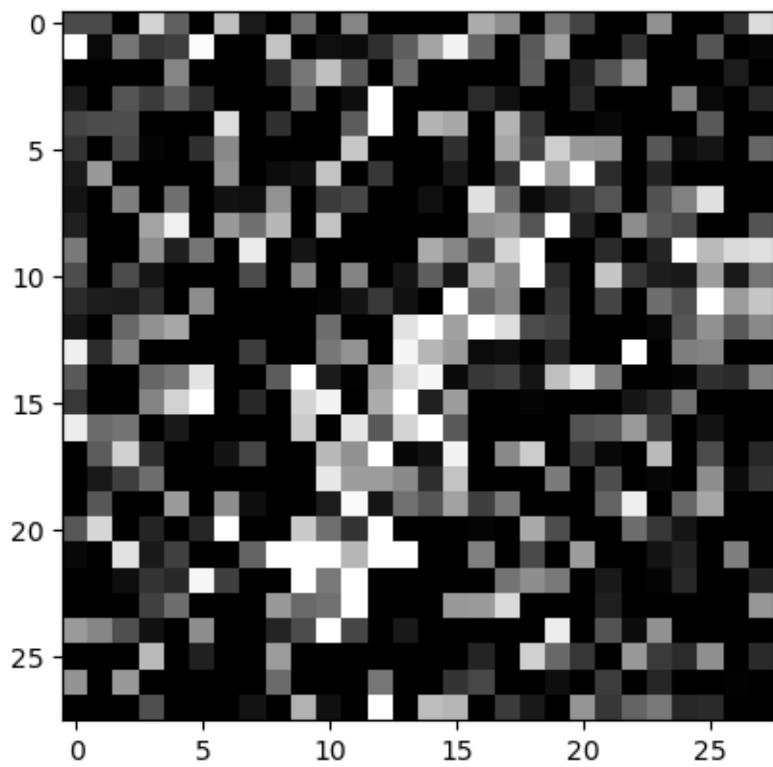
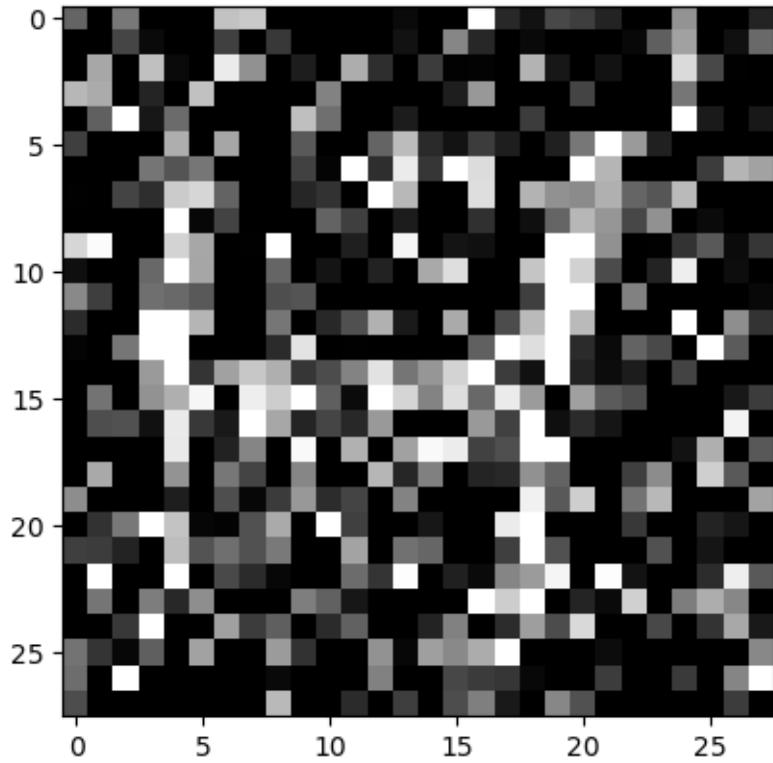


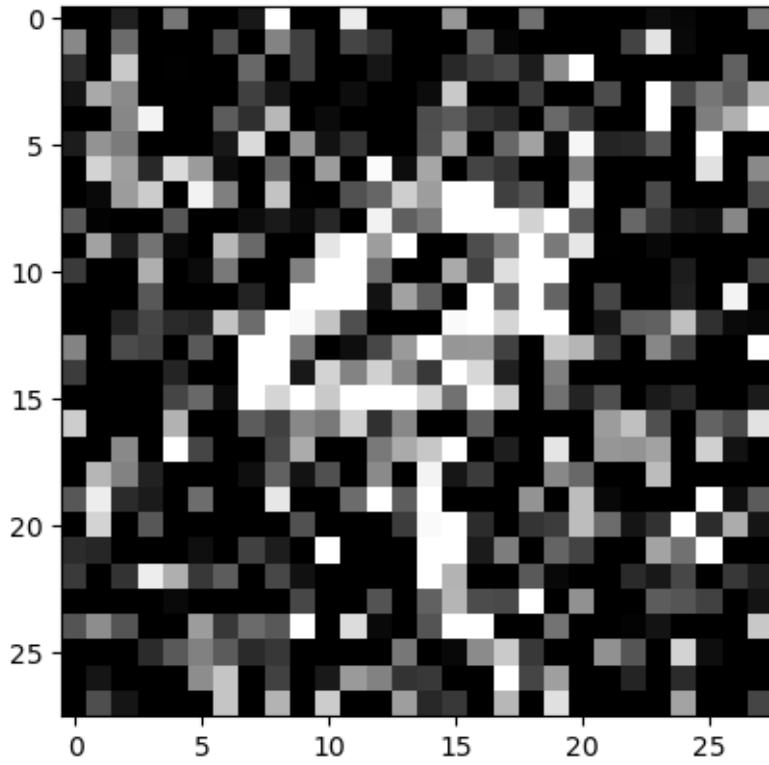












1.0.4 4. Design the Convolutional Autoencoder

The autoencoder should have:

1. Encoder: - A series of convolutional layers to extract features and reduce spatial dimensions. - Pooling layers to downsample the feature maps.
2. Decoder: - Transposed convolution (or upsampling) layers to restore spatial dimensions. - A final convolutional layer to reconstruct the cleaned image.

3. Architecture:

- Input: Shape (28, 28, 1) (grayscale MNIST images).
- Encoder:
 - Conv2D with 32 filters, kernel size (3, 3), ReLU activation, and same padding.
 - MaxPooling2D with pool size (2, 2) to reduce dimensions.
 - Conv2D with 64 filters, kernel size (3, 3), ReLU activation, and same padding.
 - MaxPooling2D with pool size (2, 2).
- Decoder:
 - Conv2D with 64 filters, kernel size (3, 3), ReLU activation, and same padding.
 - UpSampling2D to increase dimensions.
 - Conv2D with 32 filters, kernel size (3, 3), ReLU activation, and same padding.
 - UpSampling2D.

- Conv2D with 1 filter, kernel size (3, 3), sigmoid activation, and same padding (output layer).

```
[24]: from tensorflow.keras import layers, models

input_shape = (28, 28, 1)

autoencoder = models.Sequential([
    # Encoding
    layers.Conv2D(32, (3, 3), activation='relu', padding='same',
    input_shape=input_shape),
    layers.MaxPooling2D(pool_size=(2, 2), padding='same'),
    layers.Conv2D(64, (3, 3), activation='relu', padding='same'),
    layers.MaxPooling2D(pool_size=(2, 2), padding='same'),

    # Decoding
    layers.Conv2D(64, (3, 3), activation='relu', padding='same'),
    layers.UpSampling2D((2, 2)),
    layers.Conv2D(32, (3, 3), activation='relu', padding='same'),
    layers.UpSampling2D((2, 2)),
    layers.Conv2D(1, (3, 3), activation='sigmoid', padding='same')
])
```

/opt/anaconda3/lib/python3.12/site-packages/keras/src/layers/convolutional/base_conv.py:107: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.

```
super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
[25]: autoencoder.summary()
```

Model: "sequential_2"

| Layer (type) | Output Shape | Param # |
|--------------------------------|--------------------|---------|
| conv2d_11 (Conv2D) | (None, 28, 28, 32) | 320 |
| max_pooling2d_5 (MaxPooling2D) | (None, 14, 14, 32) | 0 |
| conv2d_12 (Conv2D) | (None, 14, 14, 64) | 18,496 |
| max_pooling2d_6 (MaxPooling2D) | (None, 7, 7, 64) | 0 |
| conv2d_13 (Conv2D) | (None, 7, 7, 64) | 36,928 |
| up_sampling2d_4 (UpSampling2D) | (None, 14, 14, 64) | 0 |

| | | |
|--------------------------------|--------------------|--------|
| conv2d_14 (Conv2D) | (None, 14, 14, 32) | 18,464 |
| up_sampling2d_5 (UpSampling2D) | (None, 28, 28, 32) | 0 |
| conv2d_15 (Conv2D) | (None, 28, 28, 1) | 289 |

Total params: 74,497 (291.00 KB)

Trainable params: 74,497 (291.00 KB)

Non-trainable params: 0 (0.00 B)

```
[28]: autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

1.0.5 5. Train the Autoencoder

1. Use the noisy images as inputs and the original images as targets.
2. Train the model for 10 epochs with a batch size of 128

```
[29]: # Train the Autoencoder
autoencoder.fit(
    x_train_noisy, x_train,
    epochs=20,
    batch_size=128,
    validation_data=(x_test_noisy, x_test)
)
```

```
Epoch 1/20
469/469           69s 143ms/step -
loss: 0.2270 - val_loss: 0.1129
Epoch 2/20
469/469           71s 151ms/step -
loss: 0.1111 - val_loss: 0.1054
Epoch 3/20
469/469           73s 155ms/step -
loss: 0.1052 - val_loss: 0.1019
Epoch 4/20
469/469           76s 161ms/step -
loss: 0.1022 - val_loss: 0.1002
Epoch 5/20
469/469           67s 142ms/step -
loss: 0.1003 - val_loss: 0.0985
Epoch 6/20
```

```
469/469          64s 137ms/step -
loss: 0.0992 - val_loss: 0.0976
Epoch 7/20
469/469          66s 141ms/step -
loss: 0.0979 - val_loss: 0.0967
Epoch 8/20
469/469          66s 140ms/step -
loss: 0.0972 - val_loss: 0.0960
Epoch 9/20
469/469          62s 132ms/step -
loss: 0.0963 - val_loss: 0.0960
Epoch 10/20
469/469          70s 149ms/step -
loss: 0.0959 - val_loss: 0.0954
Epoch 11/20
469/469          68s 145ms/step -
loss: 0.0954 - val_loss: 0.0948
Epoch 12/20
469/469          68s 145ms/step -
loss: 0.0948 - val_loss: 0.0944
Epoch 13/20
469/469          69s 148ms/step -
loss: 0.0943 - val_loss: 0.0943
Epoch 14/20
469/469          67s 143ms/step -
loss: 0.0944 - val_loss: 0.0939
Epoch 15/20
469/469          68s 144ms/step -
loss: 0.0938 - val_loss: 0.0937
Epoch 16/20
469/469          68s 144ms/step -
loss: 0.0938 - val_loss: 0.0935
Epoch 17/20
469/469          70s 150ms/step -
loss: 0.0935 - val_loss: 0.0934
Epoch 18/20
469/469          71s 152ms/step -
loss: 0.0931 - val_loss: 0.0933
Epoch 19/20
469/469          67s 142ms/step -
loss: 0.0932 - val_loss: 0.0931
Epoch 20/20
469/469          66s 140ms/step -
loss: 0.0930 - val_loss: 0.0931
```

[29]: <keras.src.callbacks.history.History at 0x1334494c0>

1.0.6 6. Evaluate and Visualize the Results

1. Use the trained autoencoder to clean the noisy test images.
2. Compare the original, noisy, and denoised images

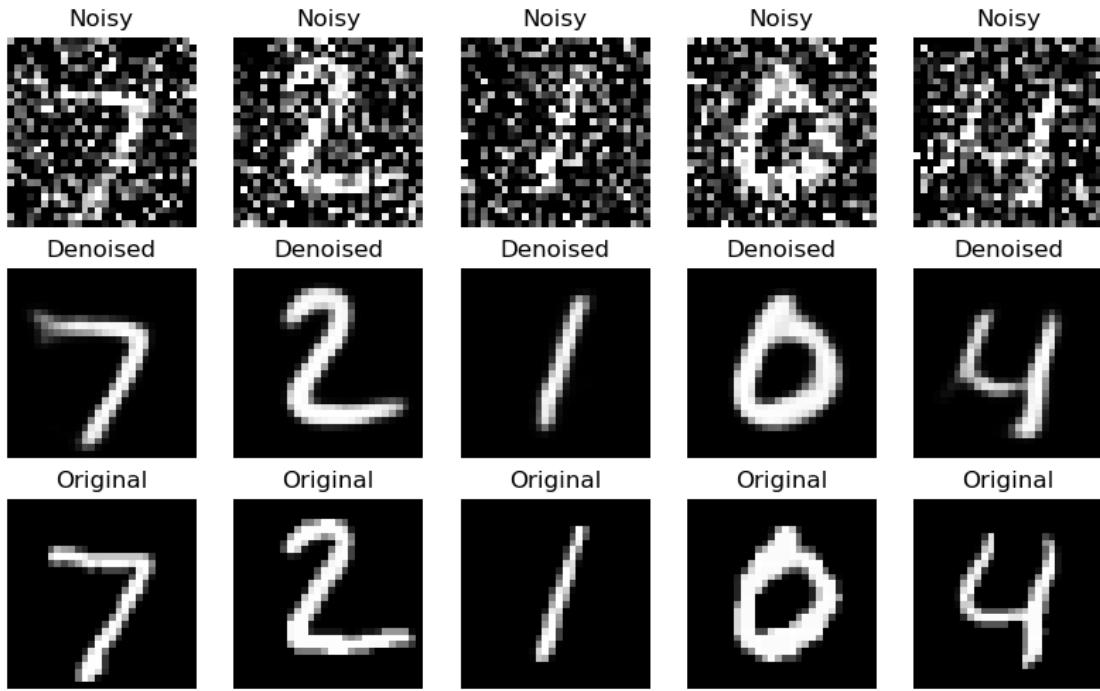
```
[30]: # Denoise the test images
denoised_images = autoencoder.predict(x_test_noisy)

# Visualize noisy and denoised images
n = 5 # Number of images to display
plt.figure(figsize=(10, 6))
for i in range(n):
    # Noisy images
    ax = plt.subplot(3, n, i + 1)
    plt.imshow(x_test_noisy[i].squeeze(), cmap="gray")
    plt.title("Noisy")
    plt.axis("off")

    # Denoised images
    ax = plt.subplot(3, n, i + 1 + n)
    plt.imshow(denoised_images[i].squeeze(), cmap="gray")
    plt.title("Denoised")
    plt.axis("off")

    # Original images
    ax = plt.subplot(3, n, i + 1 + 2*n)
    plt.imshow(x_test[i].squeeze(), cmap="gray")
    plt.title("Original")
    plt.axis("off")
plt.show()
```

313/313 3s 9ms/step



```
[31]: # Evaluate the model
test_loss = autoencoder.evaluate(x_test_noisy, x_test)
print(f'Test Loss: {test_loss}')
```

```
313/313          3s 8ms/step -
loss: 0.0924
Test Loss: 0.09309321641921997
```

```
[ ]:
```