Autoencoder (AE) – Image Compression & Reconstruction

Use an Autoencoder to:

- Compress image data via the encoder
- Reconstruct it back via the decoder
- Evaluate how well the model recreates the original digits

1. Environment Setup

```
!pip install tensorflow
```

```
Requirement already satisfied: tensorflow in /usr/local/lib/python3.11/dist-packages (2.18.0)
Requirement already satisfied: absl-py>=1.0.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.4.0)
Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=24.3.25 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (25.2.10)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (0.6.0)
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Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-packages (from tensorflow) (24.2)
Requirement already satisfied: protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<6.0.0dev,>=3.20.3 in /usr/local/lib/python
Requirement already satisfied: requests<3,>=2.21.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.32.3)
Requirement already satisfied: setuptools in /usr/local/lib/python3.11/dist-packages (from tensorflow) (75.2.0)
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.17.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.1.0)
Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (4.14.0)
Requirement already satisfied: wrapt>=1.11.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.17.2)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (1.73.0)
Requirement already satisfied: tensorboard<2.19,>=2.18 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.18.0)
Requirement already satisfied: keras>=3.5.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.8.0)
Requirement already satisfied: numpy<2.1.0,>=1.26.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (2.0.2)
Requirement already satisfied: h5py>=3.11.0 in /usr/local/lib/python3.11/dist-packages (from tensorflow) (3.14.0)
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Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18->tensorflow) (3.
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>
Requirement already satisfied: werkzeug>=1.0.1 in /usr/local/lib/python3.11/dist-packages (from tensorboard<2.19,>=2.18->tensorflow) (3.
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Requirement already satisfied: pygments<3.0.0,>=2.13.0 in /usr/local/lib/python3.11/dist-packages (from rich->keras>=3.5.0->tensorflow)
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```

2. Load MNIST Dataset

```
import tensorflow as tf
from tensorflow.keras.datasets import mnist
import matplotlib.pyplot as plt
import numpy as np

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

# Normalize and flatten
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0
x_train = x_train.reshape((-1, 28*28))
x_test = x_test.reshape((-1, 28*28))
```

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

3. Build the Autoencoder Model

```
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Input, Dense

# Input layer
input_img = Input(shape=(784,))

# Encoder
encoded = Dense(64, activation='relu')(input_img)

# Decoder
decoded = Dense(784, activation='sigmoid')(encoded)

# Autoencoder model
autoencoder = Model(input_img, decoded)

# Compile model
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')
```

4. Train the Model

```
autoencoder.fit(x_train, x_train,
                epochs=20,
                batch_size=256,
                shuffle=True,
                validation_data=(x_test, x_test))
```

```
Epoch 1/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 5s 16ms/step - loss: 0.3501 - val_loss: 0.1595
Epoch 2/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 4s 12ms/step - loss: 0.1509 - val_loss: 0.1257
Epoch 3/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.1226 - val_loss: 0.1084
Epoch 4/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 4s 17ms/step - loss: 0.1067 - val_loss: 0.0981
Epoch 5/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0970 - val_loss: 0.0907
Epoch 6/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0903 - val_loss: 0.0857
Epoch 7/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 6s 15ms/step - loss: 0.0857 - val_loss: 0.0823
Epoch 8/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 13ms/step - loss: 0.0822 - val_loss: 0.0796
Epoch 9/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0800 - val_loss: 0.0778
Epoch 10/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0782 - val_loss: 0.0766
Epoch 11/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 6s 18ms/step - loss: 0.0770 - val_loss: 0.0757
Epoch 12/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 4s 13ms/step - loss: 0.0761 - val_loss: 0.0751
Epoch 13/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0755 - val_loss: 0.0745
Epoch 14/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 6s 17ms/step - loss: 0.0751 - val_loss: 0.0742
Epoch 15/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0749 - val_loss: 0.0739
Epoch 16/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 5s 12ms/step - loss: 0.0746 - val_loss: 0.0737
Epoch 17/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 6s 14ms/step - loss: 0.0743 - val_loss: 0.0735
Epoch 18/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 11ms/step - loss: 0.0742 - val_loss: 0.0734
Epoch 19/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 12ms/step - loss: 0.0740 - val_loss: 0.0733
Epoch 20/20
235/235 ━━━━━━━━━━━━━━━━━━━━ 3s 13ms/step - loss: 0.0738 - val_loss: 0.0732
<keras.src.callbacks.history.History at 0x7e9c35313390>
```

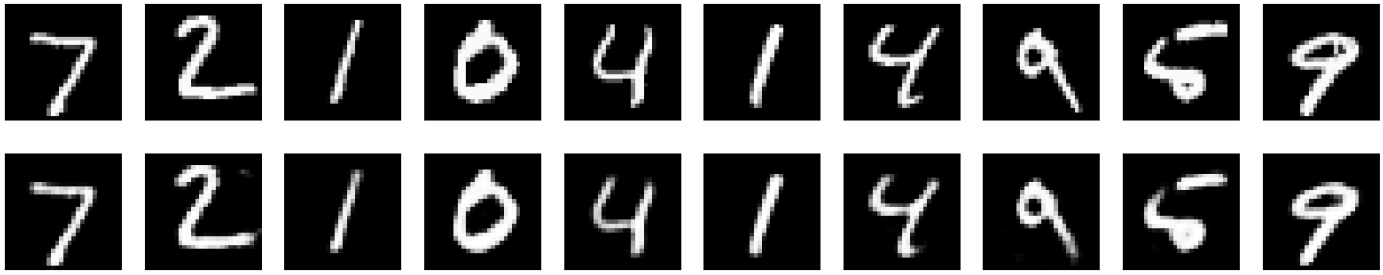
5. Visualize Original vs. Reconstructed Images

```
# Predict on test data
decoded_imgs = autoencoder.predict(x_test)

# Plot original and reconstructed images
n = 10  # number of images
plt.figure(figsize=(20, 4))
for i in range(n):
    # Original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28), cmap='gray')
    plt.axis('off')

    # Reconstructed
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28), cmap='gray')
    plt.axis('off')
plt.show()
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
```



Autoencoders can reduce data dimensionality and reconstruct it with some loss.

This basic AE uses a 64-neuron bottleneck layer to learn compressed features.

Visualization helps compare original vs. reconstructed performance visually.