Experiment No.2 Autoencoders and Variational Autoencoders (VAE)

1. Build a simple AE model for Dimensionality Reduction and Denoising.

2.Generate realistic faces or interpolate between facial features for creative applications in entertainment and design using VAE.

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Collab Link : https://colab.research.google.com/drive/1acpDVgKMXwD92upm9EM2_ywginPzTq18?usp=sharing

Part A — Autoencoder (AE)

Theory (quick): An autoencoder learns an encoding function `z = f(x)` and a decoding function `x' = g(z)` by minimizing reconstruction loss `||x - x'||^2`. The *bottleneck* (latent vector) acts as dimensionality reduction. For denoising, we train the AE to reconstruct clean inputs from noisy inputs.

```python
In [ ]:
# Imports
import numpy as np
import matplotlib.pyplot as plt
from sklearn.datasets import load_digits
from sklearn.model_selection import train_test_split
from keras.layers import Input, Dense, Flatten, Reshape
from keras.models import Model
from keras.datasets import mnist


print("numpy:", np.__version__)
```

```
numpy: 2.0.2
```

```python
In [ ]:
# Load and normalize MNIST
(x_train, _), (x_test, _) = mnist.load_data()
x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.

# Add noise
noise_factor = 0.5
x_train_noisy = x_train + noise_factor * np.random.normal(loc=0.0, scale=1.0,
x_test_noisy = x_test + noise_factor * np.random.normal(loc=0.0, scale=1.0, si
x_train_noisy = np.clip(x_train_noisy, 0., 1.)
x_test_noisy = np.clip(x_test_noisy, 0., 1.)
```

```python
# Model
input_img = Input(shape=(28, 28))
flat = Flatten()(input_img)
encoded = Dense(64, activation='relu')(flat)
bottleneck = Dense(16, activation='relu')(encoded)
decoded = Dense(64, activation='relu')(bottleneck)
decoded = Dense(28*28, activation='sigmoid')(decoded)
decoded = Reshape((28, 28))(decoded)
autoencoder = Model(input_img, decoded)
autoencoder.compile(optimizer='adam', loss='mse')

# Training
autoencoder.fit(
    x_train_noisy, x_train,
    epochs=10,
    batch_size=256,
    shuffle=True,
    validation_data=(x_test_noisy, x_test),
    verbose=2
)
```

```
Epoch 1/10
235/235 - 4s - 15ms/step - loss: 0.0741 - val_loss: 0.0528
Epoch 2/10
235/235 - 2s - 10ms/step - loss: 0.0474 - val_loss: 0.0418
Epoch 3/10
235/235 - 4s - 18ms/step - loss: 0.0389 - val_loss: 0.0363
Epoch 4/10
235/235 - 5s - 19ms/step - loss: 0.0354 - val_loss: 0.0338
Epoch 5/10
235/235 - 3s - 11ms/step - loss: 0.0333 - val_loss: 0.0323
Epoch 6/10
235/235 - 2s - 9ms/step - loss: 0.0321 - val_loss: 0.0313
Epoch 7/10
235/235 - 2s - 10ms/step - loss: 0.0313 - val_loss: 0.0305
Epoch 8/10
235/235 - 3s - 13ms/step - loss: 0.0304 - val_loss: 0.0297
Epoch 9/10
235/235 - 2s - 9ms/step - loss: 0.0297 - val_loss: 0.0291
Epoch 10/10
235/235 - 2s - 9ms/step - loss: 0.0292 - val_loss: 0.0287
```

Out[ ]: `<keras.src.callbacks.history.History at 0x7ea3ef813560>`

In [ ]:
```python
def display_random_results(n=10):
    # Ensure the sample size does not exceed the number of test images
    n = min(n, x_test.shape[0])
    idxs = np.random.choice(x_test.shape[0], n, replace=False)
    noisy_imgs = x_test_noisy[idxs]
    decoded_imgs = autoencoder.predict(noisy_imgs)
    originals = x_test[idxs]
    plt.figure(figsize=(18, 6))
    for i in range(n):
```
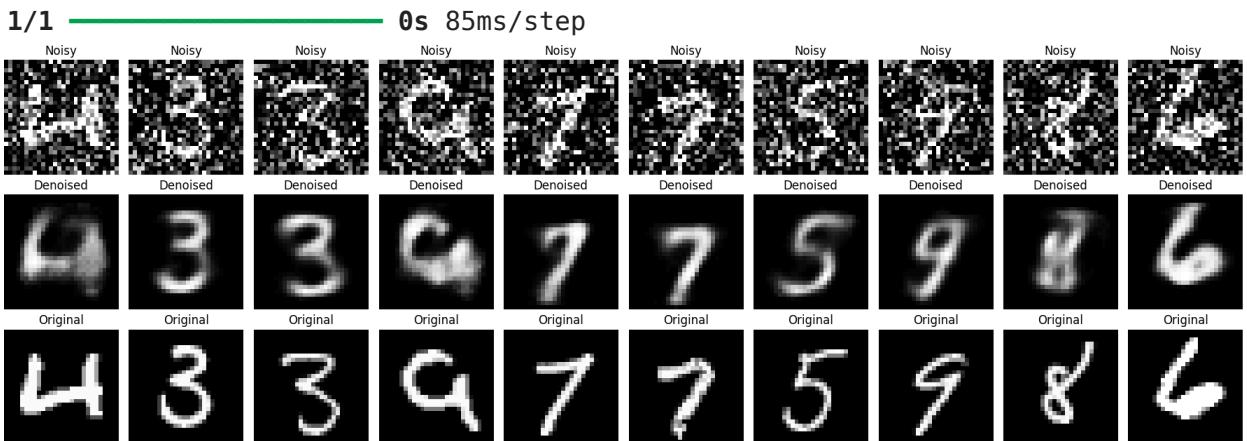
```python
        # Noisy
        ax = plt.subplot(3, n, i + 1)
        plt.imshow(noisy_imgs[i], cmap='gray')
        plt.title("Noisy")
        plt.axis("off")
        # Denoised
        ax = plt.subplot(3, n, i + 1 + n)
        plt.imshow(decoded_imgs[i], cmap='gray')
        plt.title("Denoised")
        plt.axis("off")
        # Original
        ax = plt.subplot(3, n, i + 1 + 2 * n)
        plt.imshow(originals[i], cmap='gray')
        plt.title("Original")
        plt.axis("off")
    plt.tight_layout()
    plt.show()

# Call this function (can be re-run to get different results each time)
display_random_results(n=10)
```

1/1 ━━━━━━━━━━━━━━━━━━ **0s** 85ms/step


```python
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers

# Parameters
latent_dim = 2  # latent space dimension

# Load and preprocess MNIST data
(x_train, _), (x_test, _) = keras.datasets.mnist.load_data()
x_train = np.expand_dims(x_train.astype("float32") / 255., -1)
x_test = np.expand_dims(x_test.astype("float32") / 255., -1)

# Sampling layer to sample latent vector z
class Sampling(layers.Layer):
    def call(self, inputs):
        z_mean, z_log_var = inputs
        batch = tf.shape(z_mean)[0]
```

```python
        dim = tf.shape(z_mean)[1]
        epsilon = tf.random.normal(shape=(batch, dim))
        return z_mean + tf.exp(0.5 * z_log_var) * epsilon

# Build Encoder
encoder_inputs = keras.Input(shape=(28, 28, 1))
x = layers.Conv2D(32, 3, activation="relu", strides=2, padding="same")(encoder
x = layers.Conv2D(64, 3, activation="relu", strides=2, padding="same")(x)
x = layers.Flatten()(x)
x = layers.Dense(16, activation="relu")(x)
z_mean = layers.Dense(latent_dim, name="z_mean")(x)
z_log_var = layers.Dense(latent_dim, name="z_log_var")(x)
z = Sampling()([z_mean, z_log_var])
encoder = keras.Model(encoder_inputs, [z_mean, z_log_var, z], name="encoder")

# Build Decoder
latent_inputs = keras.Input(shape=(latent_dim,))
x = layers.Dense(7 * 7 * 64, activation="relu")(latent_inputs)
x = layers.Reshape((7, 7, 64))(x)
x = layers.Conv2DTranspose(64, 3, activation="relu", strides=2, padding="same"
x = layers.Conv2DTranspose(32, 3, activation="relu", strides=2, padding="same"
decoder_outputs = layers.Conv2DTranspose(1, 3, activation="sigmoid", padding="
decoder = keras.Model(latent_inputs, decoder_outputs, name="decoder")

# Custom VAE Model
class VAE(keras.Model):
    def __init__(self, encoder, decoder, **kwargs):
        super().__init__(**kwargs)
        self.encoder = encoder
        self.decoder = decoder

    def call(self, inputs):
        z_mean, z_log_var, z = self.encoder(inputs)
        return self.decoder(z)

    def compute_loss(self, data):
        z_mean, z_log_var, z = self.encoder(data)
        reconstruction = self.decoder(z)
        reconstruction_loss = tf.reduce_mean(
            tf.reduce_sum(
                keras.losses.binary_crossentropy(data, reconstruction), axis=(
            )
        )
        kl_loss = -0.5 * tf.reduce_mean(
            tf.reduce_sum(1 + z_log_var - tf.square(z_mean) - tf.exp(z_log_var
        )
        total_loss = reconstruction_loss + kl_loss
        return total_loss, reconstruction_loss, kl_loss

    def train_step(self, data):
        if isinstance(data, tuple):
            data = data[0]
        with tf.GradientTape() as tape:
```

```python
            total_loss, reconstruction_loss, kl_loss = self.compute_loss(data)
        grads = tape.gradient(total_loss, self.trainable_weights)
        self.optimizer.apply_gradients(zip(grads, self.trainable_weights))
        return {
            "loss": total_loss,
            "reconstruction_loss": reconstruction_loss,
            "kl_loss": kl_loss,
        }

    def test_step(self, data):
        if isinstance(data, tuple):
            data = data[0]
        total_loss, reconstruction_loss, kl_loss = self.compute_loss(data)
        return {
            "loss": total_loss,
            "reconstruction_loss": reconstruction_loss,
            "kl_loss": kl_loss,
        }

# Instantiate and compile model
vae = VAE(encoder, decoder)
vae.compile(optimizer=keras.optimizers.Adam())

# Train
vae.fit(x_train, epochs=10, batch_size=128, validation_data=(x_test, None))

# Function to visualize latent space digit generation
def plot_latent_space(decoder, n=15, figsize=10):
    digit_size = 28
    scale = 2.0
    figure = np.zeros((digit_size * n, digit_size * n))
    grid_x = np.linspace(-scale, scale, n)
    grid_y = np.linspace(-scale, scale, n)[::-1]
    for i, yi in enumerate(grid_y):
        for j, xi in enumerate(grid_x):
            z_sample = np.array([[xi, yi]])
            x_decoded = decoder.predict(z_sample)
            digit = x_decoded[0].reshape(digit_size, digit_size)
            figure[
                i * digit_size : (i + 1) * digit_size,
                j * digit_size : (j + 1) * digit_size,
            ] = digit
    plt.figure(figsize=(figsize, figsize))
    plt.imshow(figure, cmap="Greys_r")
    plt.axis("off")
    plt.show()

plot_latent_space(decoder)

# Function to interpolate between two points in latent space
def interpolate_digits(decoder, z_point1, z_point2, steps=10):
    z_interp = np.linspace(0, 1, steps)[:, None] * z_point2 + (1 - np.linspace
    decoded = decoder.predict(z_interp)
```

```python
    plt.figure(figsize=(20, 2))
    for i in range(steps):
        plt.subplot(1, steps, i + 1)
        plt.imshow(decoded[i].squeeze(), cmap='gray')
        plt.axis('off')
    plt.show()

# Random interpolation example
z1 = np.random.randn(1, latent_dim)
z2 = np.random.randn(1, latent_dim)
interpolate_digits(decoder, z1, z2)
```

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ts/mnist.npz
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Epoch 1/10
469/469 ───────────────────── 17s 18ms/step - kl_loss: 3.2677 - loss: 212.8385 -
reconstruction_loss: 209.5708 - val_kl_loss: 3.5892 - val_loss: 195.0343 - va
l_reconstruction_loss: 191.4451
Epoch 2/10
469/469 ───────────────────── 11s 7ms/step - kl_loss: 5.6016 - loss: 177.3980 -
reconstruction_loss: 171.7964 - val_kl_loss: 6.1706 - val_loss: 170.8236 - va
l_reconstruction_loss: 164.6530
Epoch 3/10
469/469 ───────────────────── 3s 7ms/step - kl_loss: 6.1098 - loss: 167.0207 - r
econstruction_loss: 160.9109 - val_kl_loss: 6.2652 - val_loss: 167.0290 - val_r
econstruction_loss: 160.7639
Epoch 4/10
469/469 ───────────────────── 3s 7ms/step - kl_loss: 6.2643 - loss: 162.4363 - r
econstruction_loss: 156.1719 - val_kl_loss: 6.5781 - val_loss: 159.5593 - val_r
econstruction_loss: 152.9812
Epoch 5/10
469/469 ───────────────────── 3s 7ms/step - kl_loss: 6.3740 - loss: 159.6197 - r
econstruction_loss: 153.2457 - val_kl_loss: 6.4870 - val_loss: 157.5757 - val_r
econstruction_loss: 151.0887
Epoch 6/10
469/469 ───────────────────── 3s 7ms/step - kl_loss: 6.4514 - loss: 157.7510 - r
econstruction_loss: 151.2996 - val_kl_loss: 6.5649 - val_loss: 154.2034 - val_r
econstruction_loss: 147.6386
Epoch 7/10
469/469 ───────────────────── 5s 7ms/step - kl_loss: 6.4872 - loss: 156.3780 - r
econstruction_loss: 149.8908 - val_kl_loss: 6.7549 - val_loss: 156.4792 - val_r
econstruction_loss: 149.7243
Epoch 8/10
469/469 ───────────────────── 6s 8ms/step - kl_loss: 6.5496 - loss: 155.4839 - r
econstruction_loss: 148.9343 - val_kl_loss: 6.5048 - val_loss: 154.3839 - val_r
econstruction_loss: 147.8792
Epoch 9/10
469/469 ───────────────────── 5s 7ms/step - kl_loss: 6.5558 - loss: 154.6258 - r
econstruction_loss: 148.0700 - val_kl_loss: 6.5502 - val_loss: 152.7426 - val_r
econstruction_loss: 146.1924
Epoch 10/10
469/469 ───────────────────── 3s 7ms/step - kl_loss: 6.5774 - loss: 153.8306 - r
econstruction_loss: 147.2532 - val_kl_loss: 6.5607 - val_loss: 152.8115 - val_r
econstruction_loss: 146.2508
1/1 ───────────────────── 1s 893ms/step
1/1 ───────────────────── 0s 167ms/step
1/1 ───────────────────── 0s 113ms/step
1/1 ───────────────────── 0s 86ms/step
1/1 ───────────────────── 0s 29ms/step
1/1 ───────────────────── 0s 28ms/step
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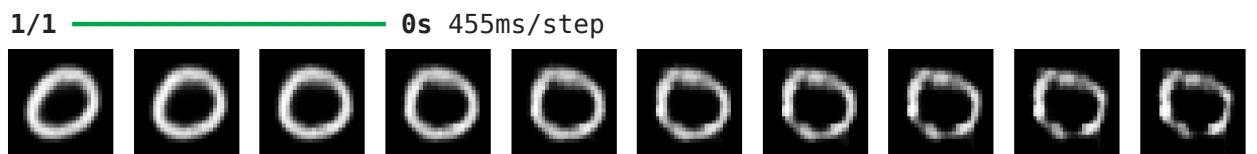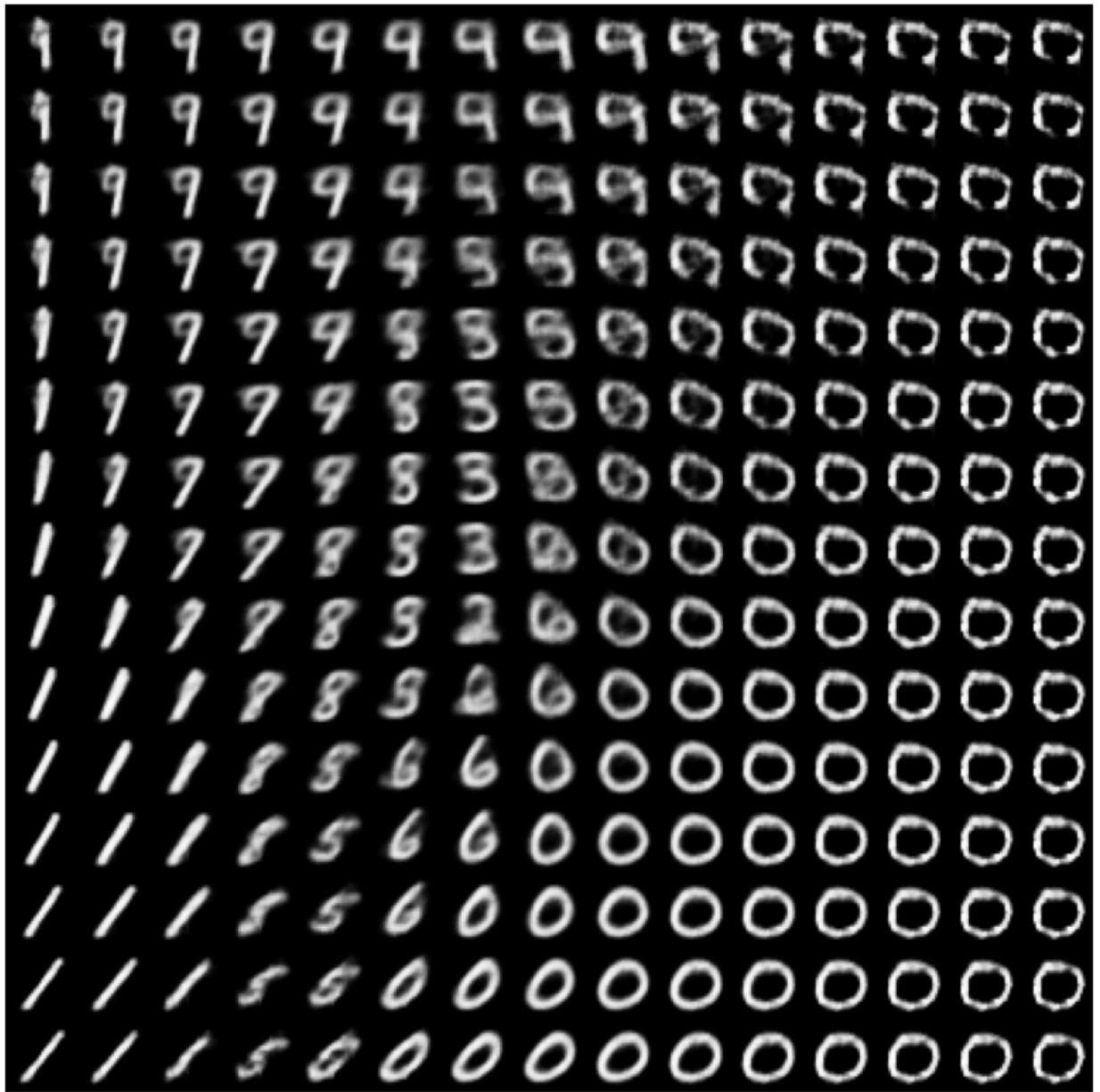
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1/1 ——————————————— 0s 28ms/step
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```

Part B — Variational Autoencoder (VAE) for Faces

Theory (quick): A VAE encodes inputs into a latent distribution `q(z|x)` (mean and log-variance). During training we sample `z ~ q(z|x)` using the *reparameterization trick*: `z = mu + exp(0.5*logvar)*epsilon`. The objective is reconstruction loss plus KL divergence between `q(z|x)` and prior `p(z)=N(0,I)`.

We'll use the **Oliveitti faces** dataset (grayscale 64x64) available from
`sklearn.datasets.fetch_olivetti_faces`.

We'll implement a small convolutional VAE in Keras and include code to:

- Train the VAE
- Sample new faces from prior `N(0,I)`
- Interpolate in latent space between two faces and decode intermediate images

In [ ]:
```python
# Imports & dataset for VAE
import numpy as np
from sklearn.datasets import fetch_olivetti_faces
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt

# load faces
faces = fetch_olivetti_faces(shuffle=True, random_state=42)
Xf = faces.images.astype("float32")  # shape (400, 64, 64)
Xf = Xf[..., np.newaxis]  # (n,64,64,1)
print("Faces shape:", Xf.shape)

Xf_train, Xf_test = train_test_split(Xf, test_size=0.2, random_state=42)
```

```
downloading Olivetti faces from https://ndownloader.figshare.com/files/5976027
to /root/scikit_learn_data
Faces shape: (400, 64, 64, 1)
```

In [ ]:
```python
# VAE implementation (convolutional) using tensorflow.keras
# Import tensorflow and keras modules
try:
    import tensorflow as tf
    from tensorflow.keras import layers, Model
except Exception as e:
    raise ImportError("TensorFlow not available. Install via: pip install tens


img_shape = Xf_train.shape[1:]  # (64, 64, 1)
latent_dim = 64


# Define the Encoder
def build_encoder(img_shape, latent_dim):
    enc_inputs = layers.Input(shape=img_shape)
    x = layers.Conv2D(32, 3, strides=2, padding="same", activation="relu")(enc
    x = layers.Conv2D(64, 3, strides=2, padding="same", activation="relu")(x)
    x = layers.Conv2D(128, 3, strides=2, padding="same", activation="relu")(x)
    x = layers.Flatten()(x)
    x = layers.Dense(256, activation="relu")(x)
    z_mean = layers.Dense(latent_dim, name="z_mean")(x)
    z_logvar = layers.Dense(latent_dim, name="z_logvar")(x)
    return Model(enc_inputs, [z_mean, z_logvar], name="encoder")
```

```python
# Define the Decoder
def build_decoder(latent_dim):
    latent_inputs = layers.Input(shape=(latent_dim,))
    x = layers.Dense(8 * 8 * 128, activation="relu")(latent_inputs)
    x = layers.Reshape((8, 8, 128))(x)
    x = layers.Conv2DTranspose(128, 3, strides=2, padding="same", activation="
    x = layers.Conv2DTranspose(64, 3, strides=2, padding="same", activation="r
    x = layers.Conv2DTranspose(32, 3, strides=2, padding="same", activation="r
    dec_outputs = layers.Conv2D(1, 3, activation="sigmoid", padding="same")(x)
    return Model(latent_inputs, dec_outputs, name="decoder")


# Define VAE as a custom Model
class VAE(tf.keras.Model):
    def __init__(self, encoder, decoder, **kwargs):
        super().__init__(**kwargs)
        self.encoder = encoder
        self.decoder = decoder
        self.total_loss_tracker = tf.keras.metrics.Mean(name="total_loss")
        self.reconstruction_loss_tracker = tf.keras.metrics.Mean(name="reconst
        self.kl_loss_tracker = tf.keras.metrics.Mean(name="kl_loss")

    @property
    def metrics(self):
        return [
            self.total_loss_tracker,
            self.reconstruction_loss_tracker,
            self.kl_loss_tracker,
        ]

    def call(self, data):
        z_mean, z_logvar = self.encoder(data)
        batch = tf.shape(z_mean)[0]
        dim = tf.shape(z_mean)[1]
        epsilon = tf.random.normal(shape=(batch, dim))
        z = z_mean + tf.exp(0.5 * z_logvar) * epsilon
        reconstruction = self.decoder(z)
        return z_mean, z_logvar, reconstruction

    def train_step(self, data):
        with tf.GradientTape() as tape:
            z_mean, z_logvar, reconstruction = self(data)
            reconstruction_loss = tf.reduce_mean(
                tf.keras.losses.binary_crossentropy(
                    tf.keras.layers.Flatten()(data),
                    tf.keras.layers.Flatten()(reconstruction),
                )
            )
            kl_loss = -0.5 * tf.reduce_sum(1 + z_logvar - tf.square(z_mean) -
            kl_loss = tf.reduce_mean(kl_loss)
            total_loss = reconstruction_loss + kl_loss
```

```python
        grads = tape.gradient(total_loss, self.trainable_weights)
        self.optimizer.apply_gradients(zip(grads, self.trainable_weights))
        self.total_loss_tracker.update_state(total_loss)
        self.reconstruction_loss_tracker.update_state(reconstruction_loss)
        self.kl_loss_tracker.update_state(kl_loss)
        return {
            "loss": self.total_loss_tracker.result(),
            "reconstruction_loss": self.reconstruction_loss_tracker.result(),
            "kl_loss": self.kl_loss_tracker.result(),
        }

    def test_step(self, data):
        z_mean, z_logvar, reconstruction = self(data)
        reconstruction_loss = tf.reduce_mean(
            tf.keras.losses.binary_crossentropy(
                tf.keras.layers.Flatten()(data),
                tf.keras.layers.Flatten()(reconstruction),
            )
        )
        kl_loss = -0.5 * tf.reduce_sum(1 + z_logvar - tf.square(z_mean) - tf.e
        kl_loss = tf.reduce_mean(kl_loss)
        total_loss = reconstruction_loss + kl_loss
        self.total_loss_tracker.update_state(total_loss)
        self.reconstruction_loss_tracker.update_state(reconstruction_loss)
        self.kl_loss_tracker.update_state(kl_loss)
        return {
            "loss": self.total_loss_tracker.result(),
            "reconstruction_loss": self.reconstruction_loss_tracker.result(),
            "kl_loss": self.kl_loss_tracker.result(),
        }


# Instantiate and compile the VAE model
encoder = build_encoder(img_shape, latent_dim)
decoder = build_decoder(latent_dim)
vae = VAE(encoder, decoder)
vae.compile(optimizer=tf.keras.optimizers.Adam())


# Show summaries
vae.encoder.summary()
vae.decoder.summary()
```

Model: "encoder"

Layer (type)	Output Shape	Param #	Connected to
input_layer_8 (InputLayer)	(None, 64, 64, 1)	0	-
conv2d_14 (Conv2D)	(None, 32, 32, 32)	320	input_layer_8[0]…
conv2d_15 (Conv2D)	(None, 16, 16, 64)	18,496	conv2d_14[0][0]
conv2d_16 (Conv2D)	(None, 8, 8, 128)	73,856	conv2d_15[0][0]
flatten_14 (Flatten)	(None, 8192)	0	conv2d_16[0][0]
dense_8 (Dense)	(None, 256)	2,097,408	flatten_14[0][0]
z_mean (Dense)	(None, 64)	16,448	dense_8[0][0]
z_logvar (Dense)	(None, 64)	16,448	dense_8[0][0]

Total params: 2,222,976 (8.48 MB)
Trainable params: 2,222,976 (8.48 MB)
Non-trainable params: 0 (0.00 B)
Model: "decoder"

Layer (type)	Output Shape	Param #
input_layer_9 (InputLayer)	(None, 64)	0
dense_9 (Dense)	(None, 8192)	532,480
reshape_4 (Reshape)	(None, 8, 8, 128)	0
conv2d_transpose_12 (Conv2DTranspose)	(None, 16, 16, 128)	147,584
conv2d_transpose_13 (Conv2DTranspose)	(None, 32, 32, 64)	73,792
conv2d_transpose_14 (Conv2DTranspose)	(None, 64, 64, 32)	18,464
conv2d_17 (Conv2D)	(None, 64, 64, 1)	289

Total params: 772,609 (2.95 MB)
Trainable params: 772,609 (2.95 MB)
Non-trainable params: 0 (0.00 B)

```
In [ ]:  # Training VAE (reduce epochs if CPU-only)
```

```python
history = vae.fit(Xf_train, epochs=50, batch_size=32, validation_data=(Xf_test
```

```
Epoch 1/50
10/10 ──────────────────── 12s 614ms/step - kl_loss: 0.0894 - loss: 0.7809 - re
construction_loss: 0.6915 - val_kl_loss: 4.6021e-04 - val_loss: 0.6865 - val_re
construction_loss: 0.6861
Epoch 2/50
10/10 ──────────────────── 1s 23ms/step - kl_loss: 4.5130e-04 - loss: 0.6880 -
reconstruction_loss: 0.6876 - val_kl_loss: 2.8600e-04 - val_loss: 0.6828 - va
l_reconstruction_loss: 0.6825
Epoch 3/50
10/10 ──────────────────── 0s 26ms/step - kl_loss: 2.2206e-04 - loss: 0.6840 -
reconstruction_loss: 0.6838 - val_kl_loss: 6.6225e-05 - val_loss: 0.6781 - va
l_reconstruction_loss: 0.6780
Epoch 4/50
10/10 ──────────────────── 0s 18ms/step - kl_loss: 5.0599e-05 - loss: 0.6783 -
reconstruction_loss: 0.6783 - val_kl_loss: 2.5228e-05 - val_loss: 0.6748 - va
l_reconstruction_loss: 0.6748
Epoch 5/50
10/10 ──────────────────── 0s 18ms/step - kl_loss: 2.1902e-05 - loss: 0.6764 -
reconstruction_loss: 0.6764 - val_kl_loss: 1.2246e-05 - val_loss: 0.6713 - va
l_reconstruction_loss: 0.6713
Epoch 6/50
10/10 ──────────────────── 0s 17ms/step - kl_loss: 9.5395e-06 - loss: 0.6748 -
reconstruction_loss: 0.6748 - val_kl_loss: 5.6302e-06 - val_loss: 0.6709 - va
l_reconstruction_loss: 0.6709
Epoch 7/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 5.3107e-06 - loss: 0.6755 -
reconstruction_loss: 0.6754 - val_kl_loss: 4.0745e-06 - val_loss: 0.6707 - va
l_reconstruction_loss: 0.6707
Epoch 8/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 3.6541e-06 - loss: 0.6739 -
reconstruction_loss: 0.6739 - val_kl_loss: 2.9340e-06 - val_loss: 0.6711 - va
l_reconstruction_loss: 0.6711
Epoch 9/50
10/10 ──────────────────── 0s 21ms/step - kl_loss: 2.6754e-06 - loss: 0.6735 -
reconstruction_loss: 0.6735 - val_kl_loss: 2.2730e-06 - val_loss: 0.6713 - va
l_reconstruction_loss: 0.6713
Epoch 10/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.9825e-06 - loss: 0.6755 -
reconstruction_loss: 0.6755 - val_kl_loss: 1.7999e-06 - val_loss: 0.6692 - va
l_reconstruction_loss: 0.6692
Epoch 11/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.6832e-06 - loss: 0.6750 -
reconstruction_loss: 0.6750 - val_kl_loss: 1.4302e-06 - val_loss: 0.6697 - va
l_reconstruction_loss: 0.6697
Epoch 12/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.3379e-06 - loss: 0.6729 -
reconstruction_loss: 0.6729 - val_kl_loss: 1.7639e-06 - val_loss: 0.6705 - va
l_reconstruction_loss: 0.6705
Epoch 13/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.4183e-06 - loss: 0.6744 -
reconstruction_loss: 0.6744 - val_kl_loss: 1.5938e-06 - val_loss: 0.6707 - va
l_reconstruction_loss: 0.6707
Epoch 14/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 1.2194e-06 - loss: 0.6734 -
```

```
reconstruction_loss: 0.6734 - val_kl_loss: 1.3566e-06 - val_loss: 0.6698 - va
l_reconstruction_loss: 0.6698
Epoch 15/50
10/10 ──────────────── 0s 20ms/step - kl_loss: 1.1948e-06 - loss: 0.6732 -
reconstruction_loss: 0.6732 - val_kl_loss: 1.6286e-06 - val_loss: 0.6691 - va
l_reconstruction_loss: 0.6691
Epoch 16/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.1892e-06 - loss: 0.6730 -
reconstruction_loss: 0.6730 - val_kl_loss: 1.2297e-06 - val_loss: 0.6695 - va
l_reconstruction_loss: 0.6695
Epoch 17/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.0848e-06 - loss: 0.6705 -
reconstruction_loss: 0.6705 - val_kl_loss: 1.2498e-06 - val_loss: 0.6683 - va
l_reconstruction_loss: 0.6683
Epoch 18/50
10/10 ──────────────── 0s 17ms/step - kl_loss: 1.0194e-06 - loss: 0.6714 -
reconstruction_loss: 0.6714 - val_kl_loss: 1.2706e-06 - val_loss: 0.6677 - va
l_reconstruction_loss: 0.6677
Epoch 19/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.0545e-06 - loss: 0.6712 -
reconstruction_loss: 0.6712 - val_kl_loss: 1.1014e-06 - val_loss: 0.6678 - va
l_reconstruction_loss: 0.6678
Epoch 20/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 9.9616e-07 - loss: 0.6712 -
reconstruction_loss: 0.6712 - val_kl_loss: 1.0266e-06 - val_loss: 0.6676 - va
l_reconstruction_loss: 0.6676
Epoch 21/50
10/10 ──────────────── 0s 15ms/step - kl_loss: 9.5253e-07 - loss: 0.6706 -
reconstruction_loss: 0.6706 - val_kl_loss: 1.0440e-06 - val_loss: 0.6671 - va
l_reconstruction_loss: 0.6671
Epoch 22/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 9.5396e-07 - loss: 0.6689 -
reconstruction_loss: 0.6689 - val_kl_loss: 1.1536e-06 - val_loss: 0.6691 - va
l_reconstruction_loss: 0.6691
Epoch 23/50
10/10 ──────────────── 0s 17ms/step - kl_loss: 1.1465e-06 - loss: 0.6709 -
reconstruction_loss: 0.6709 - val_kl_loss: 1.3650e-06 - val_loss: 0.6675 - va
l_reconstruction_loss: 0.6675
Epoch 24/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.3288e-06 - loss: 0.6694 -
reconstruction_loss: 0.6694 - val_kl_loss: 1.8890e-06 - val_loss: 0.6662 - va
l_reconstruction_loss: 0.6662
Epoch 25/50
10/10 ──────────────── 0s 20ms/step - kl_loss: 1.4871e-06 - loss: 0.6695 -
reconstruction_loss: 0.6695 - val_kl_loss: 1.7149e-06 - val_loss: 0.6652 - va
l_reconstruction_loss: 0.6652
Epoch 26/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.4977e-06 - loss: 0.6710 -
reconstruction_loss: 0.6710 - val_kl_loss: 1.6593e-06 - val_loss: 0.6660 - va
l_reconstruction_loss: 0.6660
Epoch 27/50
10/10 ──────────────── 0s 16ms/step - kl_loss: 1.5157e-06 - loss: 0.6686 -
reconstruction_loss: 0.6686 - val_kl_loss: 1.3274e-06 - val_loss: 0.6667 - va
l_reconstruction_loss: 0.6667
```

```
Epoch 28/50
10/10 ──────────────────── 0s 17ms/step - kl_loss: 1.2731e-06 - loss: 0.6686 -
reconstruction_loss: 0.6686 - val_kl_loss: 1.3321e-06 - val_loss: 0.6671 - va
l_reconstruction_loss: 0.6671
Epoch 29/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.0938e-06 - loss: 0.6701 -
reconstruction_loss: 0.6701 - val_kl_loss: 1.1269e-06 - val_loss: 0.6677 - va
l_reconstruction_loss: 0.6677
Epoch 30/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.1092e-06 - loss: 0.6707 -
reconstruction_loss: 0.6707 - val_kl_loss: 1.3371e-06 - val_loss: 0.6653 - va
l_reconstruction_loss: 0.6653
Epoch 31/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 1.2158e-06 - loss: 0.6692 -
reconstruction_loss: 0.6692 - val_kl_loss: 1.1157e-06 - val_loss: 0.6656 - va
l_reconstruction_loss: 0.6656
Epoch 32/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 1.0561e-06 - loss: 0.6702 -
reconstruction_loss: 0.6702 - val_kl_loss: 1.5882e-06 - val_loss: 0.6656 - va
l_reconstruction_loss: 0.6656
Epoch 33/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 1.1160e-06 - loss: 0.6696 -
reconstruction_loss: 0.6696 - val_kl_loss: 1.3870e-06 - val_loss: 0.6666 - va
l_reconstruction_loss: 0.6666
Epoch 34/50
10/10 ──────────────────── 0s 24ms/step - kl_loss: 1.1757e-06 - loss: 0.6699 -
reconstruction_loss: 0.6699 - val_kl_loss: 1.1654e-06 - val_loss: 0.6660 - va
l_reconstruction_loss: 0.6660
Epoch 35/50
10/10 ──────────────────── 0s 25ms/step - kl_loss: 1.0934e-06 - loss: 0.6689 -
reconstruction_loss: 0.6689 - val_kl_loss: 1.1132e-06 - val_loss: 0.6663 - va
l_reconstruction_loss: 0.6663
Epoch 36/50
10/10 ──────────────────── 0s 24ms/step - kl_loss: 9.6411e-07 - loss: 0.6696 -
reconstruction_loss: 0.6696 - val_kl_loss: 1.1489e-06 - val_loss: 0.6651 - va
l_reconstruction_loss: 0.6651
Epoch 37/50
10/10 ──────────────────── 0s 24ms/step - kl_loss: 9.1043e-07 - loss: 0.6698 -
reconstruction_loss: 0.6698 - val_kl_loss: 8.8351e-07 - val_loss: 0.6657 - va
l_reconstruction_loss: 0.6657
Epoch 38/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 8.2068e-07 - loss: 0.6677 -
reconstruction_loss: 0.6677 - val_kl_loss: 9.7820e-07 - val_loss: 0.6658 - va
l_reconstruction_loss: 0.6658
Epoch 39/50
10/10 ──────────────────── 0s 17ms/step - kl_loss: 8.5716e-07 - loss: 0.6696 -
reconstruction_loss: 0.6696 - val_kl_loss: 1.0406e-06 - val_loss: 0.6655 - va
l_reconstruction_loss: 0.6655
Epoch 40/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 8.1418e-07 - loss: 0.6708 -
reconstruction_loss: 0.6708 - val_kl_loss: 8.6737e-07 - val_loss: 0.6656 - va
l_reconstruction_loss: 0.6656
Epoch 41/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 7.6339e-07 - loss: 0.6685 -
```

```
reconstruction_loss: 0.6685 - val_kl_loss: 7.9597e-07 - val_loss: 0.6653 - va
l_reconstruction_loss: 0.6653
Epoch 42/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 7.2487e-07 - loss: 0.6699 -
reconstruction_loss: 0.6699 - val_kl_loss: 8.5558e-07 - val_loss: 0.6644 - va
l_reconstruction_loss: 0.6644
Epoch 43/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 7.9985e-07 - loss: 0.6706 -
reconstruction_loss: 0.6706 - val_kl_loss: 9.4033e-07 - val_loss: 0.6658 - va
l_reconstruction_loss: 0.6658
Epoch 44/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 8.6340e-07 - loss: 0.6697 -
reconstruction_loss: 0.6697 - val_kl_loss: 1.1409e-06 - val_loss: 0.6666 - va
l_reconstruction_loss: 0.6666
Epoch 45/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 9.9964e-07 - loss: 0.6699 -
reconstruction_loss: 0.6699 - val_kl_loss: 1.3045e-06 - val_loss: 0.6684 - va
l_reconstruction_loss: 0.6684
Epoch 46/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.1277e-06 - loss: 0.6690 -
reconstruction_loss: 0.6690 - val_kl_loss: 1.1136e-06 - val_loss: 0.6654 - va
l_reconstruction_loss: 0.6654
Epoch 47/50
10/10 ──────────────────── 0s 20ms/step - kl_loss: 1.0300e-06 - loss: 0.6694 -
reconstruction_loss: 0.6694 - val_kl_loss: 8.3353e-07 - val_loss: 0.6660 - va
l_reconstruction_loss: 0.6660
Epoch 48/50
10/10 ──────────────────── 0s 17ms/step - kl_loss: 9.6607e-07 - loss: 0.6716 -
reconstruction_loss: 0.6716 - val_kl_loss: 1.1828e-06 - val_loss: 0.6650 - va
l_reconstruction_loss: 0.6650
Epoch 49/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 9.6418e-07 - loss: 0.6685 -
reconstruction_loss: 0.6685 - val_kl_loss: 1.0605e-06 - val_loss: 0.6667 - va
l_reconstruction_loss: 0.6666
Epoch 50/50
10/10 ──────────────────── 0s 16ms/step - kl_loss: 1.0351e-06 - loss: 0.6699 -
reconstruction_loss: 0.6699 - val_kl_loss: 9.3474e-07 - val_loss: 0.6654 - va
l_reconstruction_loss: 0.6654
```

```python
# Sampling from prior to generate new faces
n = 8
z_samples = np.random.normal(size=(n, latent_dim))
gen = vae.decoder.predict(z_samples)

plt.figure(figsize=(12, 3))
for i in range(n):
    ax = plt.subplot(1, n, i + 1)
    plt.imshow(gen[i].squeeze(), cmap="gray")
    ax.axis("off")
plt.suptitle("Samples from VAE prior (decoded)")
plt.show()

# Latent interpolation between two test faces
def interpolate(z1, z2, steps=8):
```

```python
    ratios = np.linspace(0, 1, steps)
    vecs = np.array([(1 - r) * z1 + r * z2 for r in ratios])
    return vecs

# Pick two faces indices
i1, i2 = 10, 50

# Get the latent space means for the two faces using vae.predict()
z_mean1, z_logvar1, _ = vae.predict(Xf_test[i1 : i1 + 1])
z_mean2, z_logvar2, _ = vae.predict(Xf_test[i2 : i2 + 1])

# Use means for smooth interpolation
vecs = interpolate(z_mean1[0], z_mean2[0], steps=10)

# Decode latent interpolations
decodes = vae.decoder.predict(vecs)

plt.figure(figsize=(15, 3))
for i in range(len(decodes)):
    ax = plt.subplot(1, len(decodes), i + 1)
    plt.imshow(decodes[i].squeeze(), cmap="gray")
    ax.axis("off")
plt.suptitle("Latent interpolation: face 1 -> face 2")
plt.show()
```

WARNING:tensorflow:6 out of the last 231 calls to <function TensorFlowTrainer.make_predict_function.<locals>.one_step_on_data_distributed at 0x79bf40135800> triggered tf.function retracing. Tracing is expensive and the excessive number of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2) passing tensors with different shapes, (3) passing Python objects instead of tensors. For (1), please define your @tf.function outside of the loop. For (2), @tf.function has reduce_retracing=True option that can avoid unnecessary retracing. For (3), please refer to https://www.tensorflow.org/guide/function#controlling_retracing and https://www.tensorflow.org/api_docs/python/tf/function for more details.

1/1 ─────────────────── 0s 467ms/step

Samples from VAE prior (decoded)

1/1 ─────────────────── 1s 866ms/step
1/1 ─────────────────── 0s 30ms/step
1/1 ─────────────────── 0s 348ms/step

Latent interpolation: face 1 -> face 2

```
In [4]:  import os
         os.environ['KAGGLE_USERNAME'] = "divyagatkal007"
         os.environ['KAGGLE_KEY'] = "ac9af06b64a8e90daab20b12d95b899b"


         !kaggle datasets download -d vishesh1412/celebrity-face-image-dataset
```

Dataset URL: https://www.kaggle.com/datasets/vishesh1412/celebrity-face-image-d
ataset
License(s): CC0-1.0
Downloading celebrity-face-image-dataset.zip to /content
  0% 0.00/52.9M [00:00<?, ?B/s]
100% 52.9M/52.9M [00:00<00:00, 1.22GB/s]

```
In [5]:  !unzip -o /content/celebrity-face-image-dataset.zip -d /content/data
```

```
Archive:  /content/celebrity-face-image-dataset.zip
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```

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inflating: /content/data/Celebrity Faces Dataset/Will Smith/099_d652e3b6.jpg
inflating: /content/data/Celebrity Faces Dataset/Will Smith/100_89cbf87f.jpg
```

In [6]:
```python
import os
import torch
import torch.nn as nn
import torch.optim as optim
from torchvision import transforms, datasets, utils
from torch.utils.data import DataLoader
import matplotlib.pyplot as plt

# --------------------
# Settings
# --------------------
data_dir = "/content/data/Celebrity Faces Dataset"   # your extracted folder
out_dir = "/content/outputs"
os.makedirs(out_dir, exist_ok=True)

img_size = 64
batch_size = 64          # reduce if you run out of GPU memory
latent_dim = 256
epochs = 50
lr = 1e-3
num_workers = 2
```

```python
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Device:", device)

# --------------------
# Data loader
# --------------------
transform = transforms.Compose([
    transforms.Resize((img_size, img_size)),
    transforms.ToTensor(),
    transforms.Normalize([0.5,0.5,0.5],[0.5,0.5,0.5])   # normalize to [-1,1]
])

dataset = datasets.ImageFolder(root=data_dir, transform=transform)
loader = DataLoader(dataset, batch_size=batch_size, shuffle=True, num_workers=

print("Total images:", len(dataset))
if len(dataset) == 0:
    raise SystemExit("No images found. Check data_dir path.")

# Helper: denormalize before displaying
def denorm(x):
    return (x * 0.5 + 0.5).clamp(0,1)

# --------------------
# Conv-VAE model
# --------------------
class Encoder(nn.Module):
    def __init__(self, latent_dim):
        super().__init__()
        self.conv = nn.Sequential(
            nn.Conv2d(3, 32, 4, 2, 1),   # 64 -> 32
            nn.ReLU(inplace=True),
            nn.Conv2d(32, 64, 4, 2, 1), # 32 -> 16
            nn.ReLU(inplace=True),
            nn.Conv2d(64, 128, 4, 2, 1),# 16 -> 8
            nn.ReLU(inplace=True),
            nn.Conv2d(128, 256, 4, 2, 1),# 8 -> 4
            nn.ReLU(inplace=True)
        )
        self.fc_mu = nn.Linear(256*4*4, latent_dim)
        self.fc_logvar = nn.Linear(256*4*4, latent_dim)

    def forward(self, x):
        h = self.conv(x)
        h = h.view(h.size(0), -1)
        mu = self.fc_mu(h)
        logvar = self.fc_logvar(h)
        return mu, logvar

class Decoder(nn.Module):
    def __init__(self, latent_dim):
        super().__init__()
        self.fc = nn.Linear(latent_dim, 256*4*4)
```

```python
        self.deconv = nn.Sequential(
            nn.ConvTranspose2d(256, 128, 4, 2, 1), # 4 -> 8
            nn.ReLU(inplace=True),
            nn.ConvTranspose2d(128, 64, 4, 2, 1),  # 8 -> 16
            nn.ReLU(inplace=True),
            nn.ConvTranspose2d(64, 32, 4, 2, 1),   # 16 -> 32
            nn.ReLU(inplace=True),
            nn.ConvTranspose2d(32, 3, 4, 2, 1),    # 32 -> 64
            nn.Tanh()                              # output in [-1,1]
        )

    def forward(self, z):
        h = self.fc(z)
        h = h.view(h.size(0), 256, 4, 4)
        x_hat = self.deconv(h)
        return x_hat

class VAE(nn.Module):
    def __init__(self, latent_dim):
        super().__init__()
        self.encoder = Encoder(latent_dim)
        self.decoder = Decoder(latent_dim)

    def reparameterize(self, mu, logvar):
        std = torch.exp(0.5 * logvar)
        eps = torch.randn_like(std)
        return mu + eps * std

    def forward(self, x):
        mu, logvar = self.encoder(x)
        z = self.reparameterize(mu, logvar)
        recon = self.decoder(z)
        return recon, mu, logvar

# --------------------
# Loss (MSE + KL)
# --------------------
def loss_function(recon_x, x, mu, logvar):
    recon_loss = nn.functional.mse_loss(recon_x, x, reduction='sum')
    kl_loss = -0.5 * torch.sum(1 + logvar - mu.pow(2) - logvar.exp())
    total = recon_loss + kl_loss
    return total, recon_loss, kl_loss

# --------------------
# Initialize model and optimizer
# --------------------
model = VAE(latent_dim).to(device)
optimizer = optim.Adam(model.parameters(), lr=lr)

# --------------------
# Training loop
# --------------------
model.train()
```

```python
n_images = len(dataset)
for epoch in range(1, epochs + 1):
    epoch_total = 0.0
    epoch_recon = 0.0
    epoch_kl = 0.0
    for batch_idx, (x, _) in enumerate(loader):
        x = x.to(device)
        optimizer.zero_grad()
        recon, mu, logvar = model(x)
        loss, recon_loss, kl_loss = loss_function(recon, x, mu, logvar)
        loss.backward()
        optimizer.step()

        epoch_total += loss.item()
        epoch_recon += recon_loss.item()
        epoch_kl += kl_loss.item()

    avg_total = epoch_total / n_images
    avg_recon = epoch_recon / n_images
    avg_kl = epoch_kl / n_images
    print(f"Epoch {epoch:02d}/{epochs}  Avg Total: {avg_total:.4f}  Recon: {av

    # Save intermediate reconstruction
    model.eval()
    with torch.no_grad():
        batch, _ = next(iter(loader))
        batch = batch.to(device)
        recon, _, _ = model(batch)
        n_show = min(8, batch.size(0))
        orig_and_recon = torch.cat([denorm(batch[:n_show]), denorm(recon[:n_sh
        grid = utils.make_grid(orig_and_recon, nrow=n_show)
        utils.save_image(grid, os.path.join(out_dir, f"recon_epoch_{epoch:02d}
    model.train()

# --------------------
# Save final model
# --------------------
torch.save(model.state_dict(), os.path.join(out_dir, "conv_vae_celebrity.pth")
print("Saved model to", os.path.join(out_dir, "conv_vae_celebrity.pth"))

# --------------------
# Show reconstructions + samples
# --------------------
model.eval()
with torch.no_grad():
    batch, _ = next(iter(loader))
    batch = batch.to(device)
    recon, _, _ = model(batch)
    n_show = min(8, batch.size(0))

    plt.figure(figsize=(12,4))
    for i in range(n_show):
        plt.subplot(2, n_show, i+1)
```

```python
        plt.imshow(denorm(batch[i]).permute(1,2,0).cpu())
        plt.axis("off")
    for i in range(n_show):
        plt.subplot(2, n_show, n_show + i + 1)
        plt.imshow(denorm(recon[i]).permute(1,2,0).cpu())
        plt.axis("off")
    plt.suptitle("Top: Original, Bottom: Reconstruction")
    plt.show()

    # Save final recon grid
    orig_and_recon = torch.cat([denorm(batch[:n_show]), denorm(recon[:n_show])
    grid = utils.make_grid(orig_and_recon, nrow=n_show)
    utils.save_image(grid, os.path.join(out_dir, "final_recon.png"))

    # Generate random samples
    z = torch.randn(n_show, latent_dim).to(device)
    samples = model.decoder(z)
    plt.figure(figsize=(12,2))
    for i in range(n_show):
        plt.subplot(1, n_show, i+1)
        plt.imshow(denorm(samples[i]).permute(1,2,0).cpu())
        plt.axis("off")
    plt.suptitle("Randomly Generated Faces")
    plt.show()

    utils.save_image(denorm(samples), os.path.join(out_dir, "generated_samples
    print("Saved generated samples to", os.path.join(out_dir, "generated_sampl
```

```
Device: cuda
Total images: 1800
Epoch 01/50  Avg Total: 3776.6737  Recon: 3743.9116  KL: 32.7621
Epoch 02/50  Avg Total: 2971.8880  Recon: 2915.3027  KL: 56.5852
Epoch 03/50  Avg Total: 2086.0424  Recon: 1991.5370  KL: 94.5054
Epoch 04/50  Avg Total: 1757.1587  Recon: 1646.5171  KL: 110.6415
Epoch 05/50  Avg Total: 1617.9482  Recon: 1496.1616  KL: 121.7866
Epoch 06/50  Avg Total: 1522.2299  Recon: 1393.0727  KL: 129.1572
Epoch 07/50  Avg Total: 1451.9008  Recon: 1313.6183  KL: 138.2824
Epoch 08/50  Avg Total: 1361.3307  Recon: 1219.7390  KL: 141.5916
Epoch 09/50  Avg Total: 1328.2932  Recon: 1182.4453  KL: 145.8479
Epoch 10/50  Avg Total: 1270.8047  Recon: 1122.0677  KL: 148.7370
Epoch 11/50  Avg Total: 1239.5983  Recon: 1088.8683  KL: 150.7300
Epoch 12/50  Avg Total: 1207.7888  Recon: 1052.4301  KL: 155.3587
Epoch 13/50  Avg Total: 1182.7031  Recon: 1027.6631  KL: 155.0400
Epoch 14/50  Avg Total: 1135.5032  Recon: 977.6843   KL: 157.8190
Epoch 15/50  Avg Total: 1091.3282  Recon: 933.5743   KL: 157.7540
Epoch 16/50  Avg Total: 1040.3691  Recon: 878.5519   KL: 161.8171
Epoch 17/50  Avg Total: 1018.1609  Recon: 854.7047   KL: 163.4562
Epoch 18/50  Avg Total: 982.9682   Recon: 821.2746   KL: 161.6936
Epoch 19/50  Avg Total: 958.1383   Recon: 795.7997   KL: 162.3386
Epoch 20/50  Avg Total: 928.8551   Recon: 766.3757   KL: 162.4793
Epoch 21/50  Avg Total: 921.2205   Recon: 759.3478   KL: 161.8727
Epoch 22/50  Avg Total: 902.5019   Recon: 741.2441   KL: 161.2579
Epoch 23/50  Avg Total: 881.1390   Recon: 718.1652   KL: 162.9738
Epoch 24/50  Avg Total: 869.8058   Recon: 707.7734   KL: 162.0323
Epoch 25/50  Avg Total: 877.6259   Recon: 715.4426   KL: 162.1833
Epoch 26/50  Avg Total: 838.4206   Recon: 675.9067   KL: 162.5139
Epoch 27/50  Avg Total: 818.2542   Recon: 656.0002   KL: 162.2540
Epoch 28/50  Avg Total: 803.1093   Recon: 640.2066   KL: 162.9027
Epoch 29/50  Avg Total: 788.2158   Recon: 626.3152   KL: 161.9005
Epoch 30/50  Avg Total: 777.1215   Recon: 614.6067   KL: 162.5148
Epoch 31/50  Avg Total: 773.4419   Recon: 612.4988   KL: 160.9431
Epoch 32/50  Avg Total: 762.1142   Recon: 601.3252   KL: 160.7890
Epoch 33/50  Avg Total: 756.7350   Recon: 594.3642   KL: 162.3708
Epoch 34/50  Avg Total: 739.3113   Recon: 578.6961   KL: 160.6152
Epoch 35/50  Avg Total: 730.0261   Recon: 568.6151   KL: 161.4110
Epoch 36/50  Avg Total: 719.4176   Recon: 559.3930   KL: 160.0245
Epoch 37/50  Avg Total: 709.5028   Recon: 548.8691   KL: 160.6337
Epoch 38/50  Avg Total: 700.2851   Recon: 540.7556   KL: 159.5294
Epoch 39/50  Avg Total: 696.1888   Recon: 536.9706   KL: 159.2183
Epoch 40/50  Avg Total: 689.3180   Recon: 529.5522   KL: 159.7658
Epoch 41/50  Avg Total: 694.1627   Recon: 534.6762   KL: 159.4865
Epoch 42/50  Avg Total: 677.0817   Recon: 517.7045   KL: 159.3772
Epoch 43/50  Avg Total: 666.9815   Recon: 508.1170   KL: 158.8646
Epoch 44/50  Avg Total: 673.7370   Recon: 514.2087   KL: 159.5283
Epoch 45/50  Avg Total: 661.4118   Recon: 502.3465   KL: 159.0653
Epoch 46/50  Avg Total: 651.5572   Recon: 492.8715   KL: 158.6856
Epoch 47/50  Avg Total: 643.6452   Recon: 485.5536   KL: 158.0916
Epoch 48/50  Avg Total: 636.1089   Recon: 477.9357   KL: 158.1733
Epoch 49/50  Avg Total: 632.8894   Recon: 475.1433   KL: 157.7460
Epoch 50/50  Avg Total: 626.5350   Recon: 469.6723   KL: 156.8627
Saved model to /content/outputs/conv_vae_celebrity.pth
```

Top: Original, Bottom: Reconstruction

Randomly Generated Faces

Saved generated samples to /content/outputs/generated_samples.png

In [ ]: `print('hi')`

hi