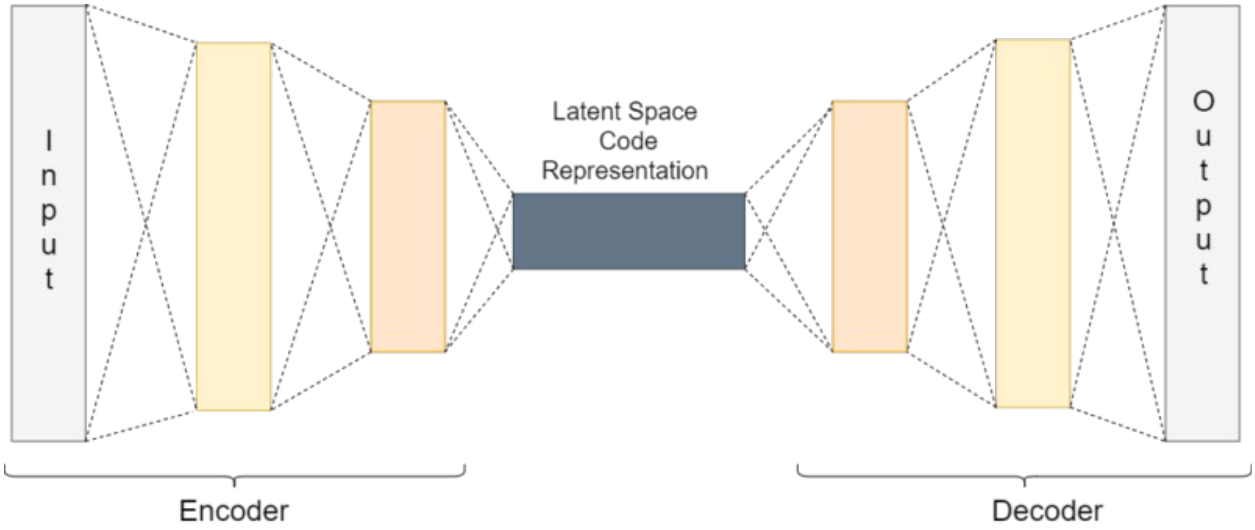
A Brief Introduction to Autoencoders

- Deep learning autoencoders are a type of neural network that can reconstruct specific images from the latent code space.
- The autoencoders obtain the latent code data from a network called the encoder network. Then we give this code as the input to the decoder network which tries to reconstruct the images that the network has been trained on.
- The following image summarizes the above theory in a simple manner.



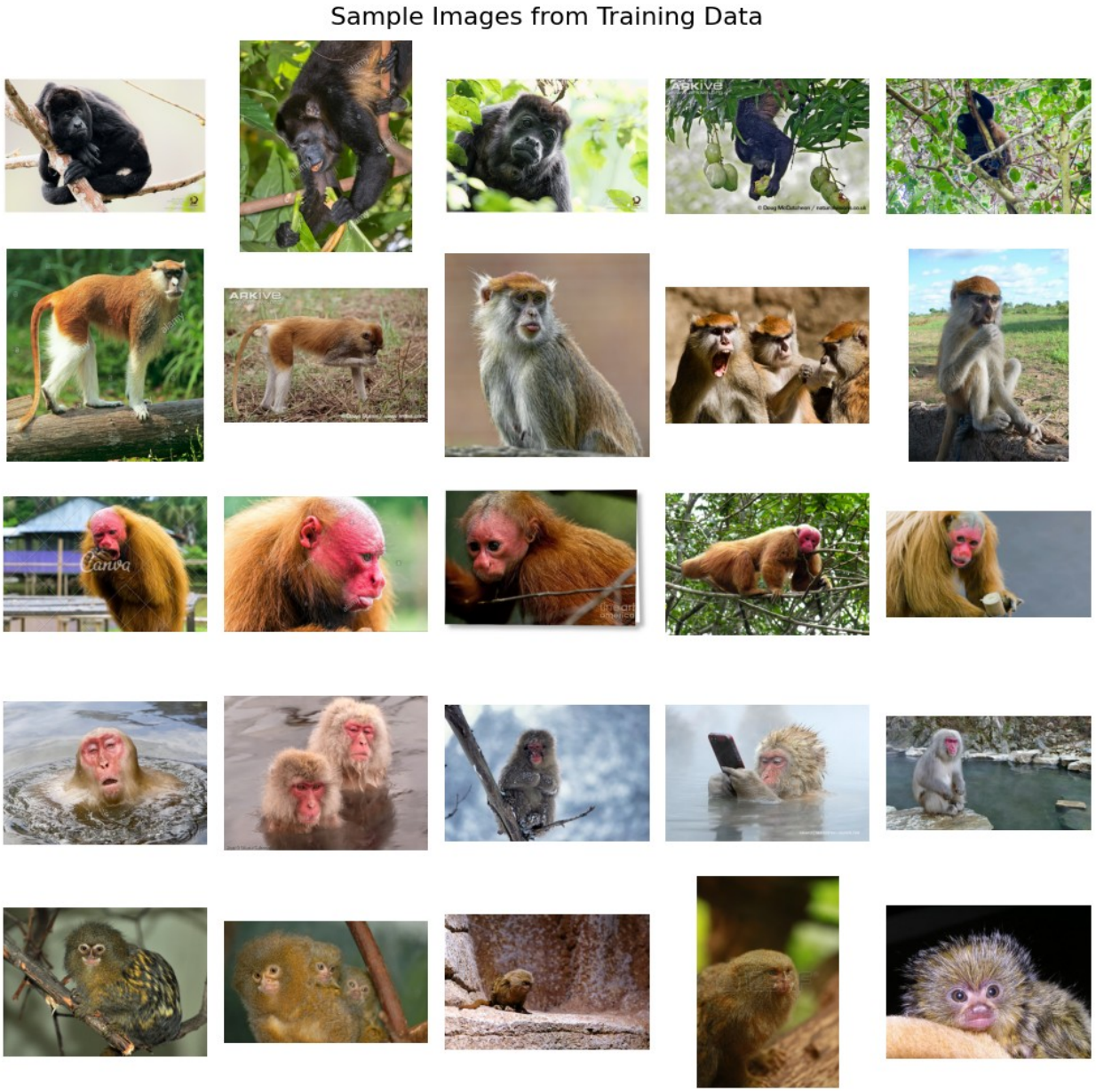
- The above image summarizes the working of an autoencoder, be it a deep or convolutional autoencoder.
- In one of my previous articles, I have covered the basics of autoencoder in deep learning. You can read the article here (Autoencoders in Deep Learning).

```
import os
import torch
import torchvision
import torch.nn as nn
import torchvision.transforms as transforms
import torch.optim as optim
import matplotlib.pyplot as plt
import torch.nn.functional as F
import seaborn as sns
from torchvision import datasets
from torch.utils.data import DataLoader
from torchvision.utils import save_image
import os
import pandas as pd
```

```
from PIL import Image
from torchinfo import summary
from torchvision.utils import save_image
from tabulate import tabulate
from tqdm import tqdm
%matplotlib inline

train_image_path="/kaggle/input/10-monkey-species/training/training/"

valid_image_path="/kaggle/input/10-monkey-species/validation/validatio
n/"
```

Visualize Images from Train Data

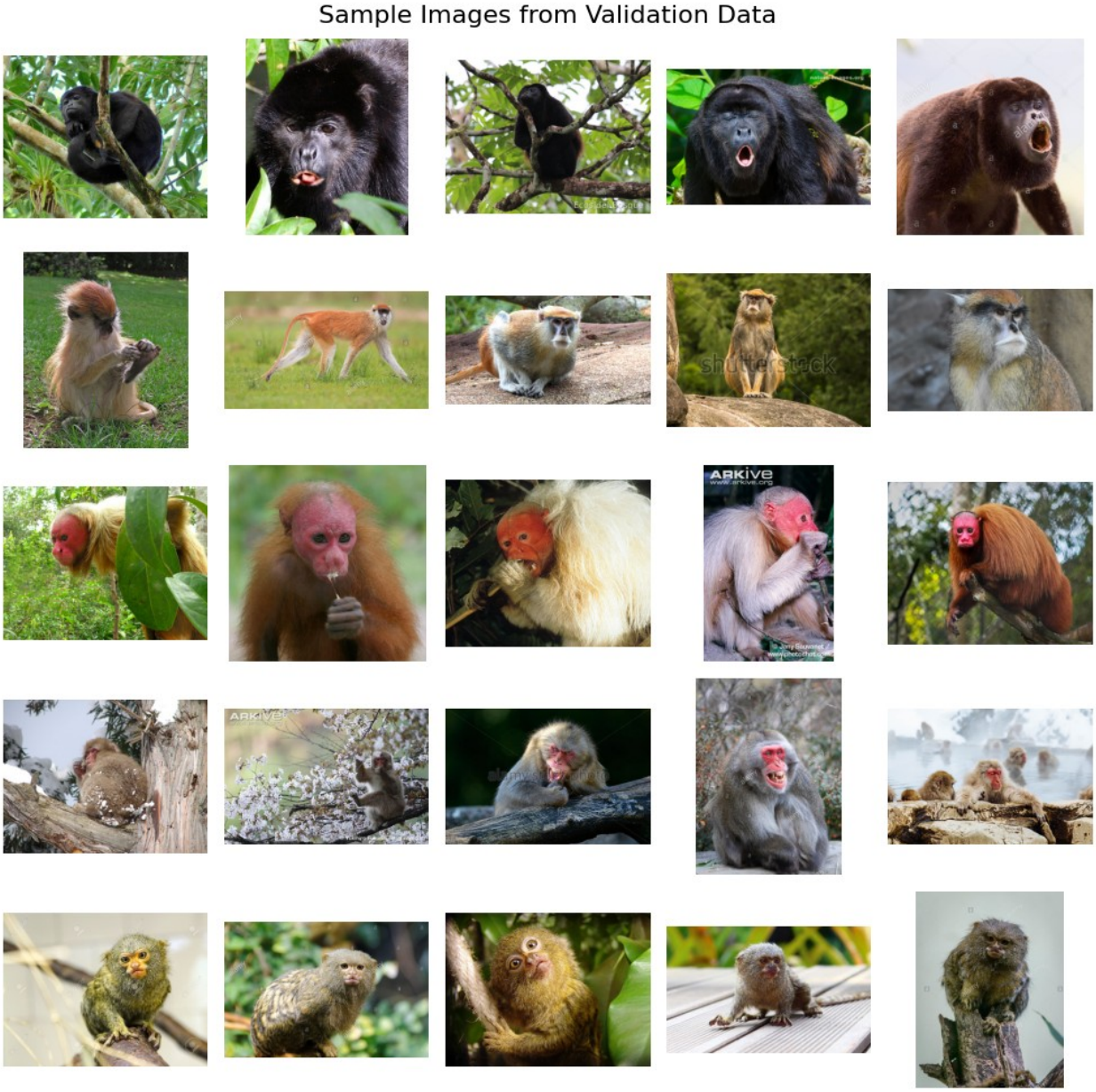
```
# Get list of class directories
class_dirs = sorted(os.listdir(train_image_path))

# Collect image file paths
image_paths = []
for class_dir in class_dirs:
    class_path = os.path.join(train_image_path, class_dir)
    if os.path.isdir(class_path):
        images = [os.path.join(class_path, img) for img in
os.listdir(class_path)[:5]]
        image_paths.extend(images)

# Select 25 images for plotting
image_paths = image_paths[:25]

# Plot images in a 5x5 grid
fig, axes = plt.subplots(5, 5, figsize=(10, 10))
fig.suptitle("Sample Images from Training Data", fontsize=16)

for ax, img_path in zip(axes.flat, image_paths):
    img = Image.open(img_path)
    ax.imshow(img)
    ax.axis("off")

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



Visualize Some IMAges from Validation Data

```
# Get list of class directories
class_dirs = sorted(os.listdir(valid_image_path))

# Collect image file paths
image_paths = []
for class_dir in class_dirs:
    class_path = os.path.join(valid_image_path, class_dir)
    if os.path.isdir(class_path):
        images = [os.path.join(class_path, img) for img in
```

```
os.listdir(class_path)[:5]]
        image_paths.extend(images)

# Select 25 images for plotting
image_paths = image_paths[:25]

# Plot images in a 5x5 grid
fig, axes = plt.subplots(5, 5, figsize=(10, 10))
fig.suptitle("Sample Images from Validation Data", fontsize=16)

for ax, img_path in zip(axes.flat, image_paths):
    img = Image.open(img_path)
    ax.imshow(img)
    ax.axis("off")

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




```
# Function to count images per class
def count_images_per_class(directory):
    class_counts = {}
    class_dirs = sorted(os.listdir(directory))
    for class_dir in class_dirs:
        class_path = os.path.join(directory, class_dir)
        if os.path.isdir(class_path):
            class_counts[class_dir] = len(os.listdir(class_path))
    return class_counts

# Get image counts
train_counts = count_images_per_class(train_image_path)
```

```
valid_counts = count_images_per_class(valid_image_path)

# Create a DataFrame for better visualization
df = pd.DataFrame({'Train': train_counts, 'Validation': valid_counts})
df = df.sort_index()

# Plot the comparison
df.plot(kind='bar', figsize=(10, 5), width=0.8)
plt.title("Train vs Validation Images Per Class")
plt.xlabel("Class")
plt.ylabel("Number of Images")
plt.xticks(rotation=45)
plt.legend(["Train", "Validation"])
plt.show()
```


```
transform = transforms.Compose([
    transforms.Resize((128, 128)),  # Resize images to 128x128
    transforms.ToTensor(),           # Convert image to tensor
    transforms.Normalize(mean=[0.5, 0.5, 0.5], std=[0.5, 0.5, 0.5])  #
Normalize
])

train_dataset = datasets.ImageFolder(root=train_image_path,
transform=transform)
valid_dataset = datasets.ImageFolder(root=valid_image_path,
transform=transform)
```

```
train_loader = DataLoader(train_dataset, batch_size=32, shuffle=True)
valid_loader = DataLoader(valid_dataset, batch_size=32, shuffle=False)

print(f"Train dataset size: {len(train_dataset)} images")
print(f"Validation dataset size: {len(valid_dataset)} images")
print(f"Class labels: {train_dataset.classes}")
```

```
Train dataset size: 1097 images
Validation dataset size: 272 images
Class labels: ['n0', 'n1', 'n2', 'n3', 'n4', 'n5', 'n6', 'n7', 'n8',
'n9']
```

```
image, label = next(iter(train_loader))
print(f"Image Shape : {image.shape}")
print(f"Label Shape : {label.shape}")
```

```
Image Shape : torch.Size([32, 3, 128, 128])
Label Shape : torch.Size([32])
```

Utility Functions

- It is always better to write some utility functions. This would save time and also avoid code repetition. Below are three utility functions that we will need along the way.

```
def get_device():
    if torch.cuda.is_available():
        device = 'cuda:0'
    else:
        device = 'cpu'
    return device

def make_dir():
    image_dir = '/kaggle/working/Monkey_Images'
    if not os.path.exists(image_dir):
        os.makedirs(image_dir)


def save_decoded_image(img, epoch):
    img = img.view(img.size(0), 3, 128, 128)  # Correct shape for
model output
    save_image(img, f'./Monkey_Images/linear_ae_image{epoch}.png')
```

- The first function, get_device() either returns the GPU device if it is available or the CPU. If you notice, this is a bit different from the one-liner code used in the PyTorch tutorials. This is because some IDEs do not recognize the torch.device() method. Therefore, to keep the code compatible for both IDE and python notebooks I just changed the code a bit.

- The second function is make_dir() which makes a directory to store the reconstructed images while training. At last, we have save_decoded_image() which saves the images that the autoencoder reconstructs.

Define the Autoencoder Network

- In this section, we will define the autoencoder network. Let's define the network first, then we will get to the code explanation.

```
class ConvAutoencoder(nn.Module):

    def __init__(self):
        super(ConvAutoencoder, self).__init__()

        # Encoder
        self.enc1 = nn.Conv2d(3, 64, 3, stride=2, padding=1)  #
128x128 -> 64x64
        self.bn1 = nn.BatchNorm2d(64)
        self.enc2 = nn.Conv2d(64, 128, 3, stride=2, padding=1)  #
64x64 -> 32x32
        self.bn2 = nn.BatchNorm2d(128)
        self.enc3 = nn.Conv2d(128, 256, 3, stride=2, padding=1)  #
32x32 -> 16x16
        self.bn3 = nn.BatchNorm2d(256)
        self.enc4 = nn.Conv2d(256, 512, 3, stride=2, padding=1)  #
16x16 -> 8x8
        self.bn4 = nn.BatchNorm2d(512)
        self.enc5 = nn.Conv2d(512, 1024, 3, stride=2, padding=1)  #
8x8 -> 4x4
        self.bn5 = nn.BatchNorm2d(1024)

        # Bottleneck
        self.fc1 = nn.Linear(1024 * 4 * 4, 2048)  # Flattened
bottleneck
        self.dropout = nn.Dropout(0.3)  # Regularization
        self.fc2 = nn.Linear(2048, 1024 * 4 * 4)  # Expand back

        # Decoder
        self.dec1 = nn.ConvTranspose2d(1024, 512, 3, stride=2,
padding=1, output_padding=1)  # 4x4 -> 8x8
        self.bn6 = nn.BatchNorm2d(512)
        self.dec2 = nn.ConvTranspose2d(512, 256, 3, stride=2,
padding=1, output_padding=1)  # 8x8 -> 16x16
        self.bn7 = nn.BatchNorm2d(256)
        self.dec3 = nn.ConvTranspose2d(256, 128, 3, stride=2,
padding=1, output_padding=1)  # 16x16 -> 32x32
        self.bn8 = nn.BatchNorm2d(128)
        self.dec4 = nn.ConvTranspose2d(128, 64, 3, stride=2,
padding=1, output_padding=1)  # 32x32 -> 64x64
```

```
        self.bn9 = nn.BatchNorm2d(64)
        self.dec5 = nn.ConvTranspose2d(64, 3, 3, stride=2, padding=1,
output_padding=1)  # 64x64 -> 128x128

    def forward(self, x):
        # Encoder
        x = F.leaky_relu(self.bn1(self.enc1(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn2(self.enc2(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn3(self.enc3(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn4(self.enc4(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn5(self.enc5(x)), negative_slope=0.01)

        # Bottleneck
        x = torch.flatten(x, start_dim=1)  # Flatten to (batch_size,
1024*4*4)
        x = F.leaky_relu(self.fc1(x), negative_slope=0.01)
        x = self.dropout(x)
        x = F.leaky_relu(self.fc2(x), negative_slope=0.01)
        x = x.view(-1, 1024, 4, 4)  # Reshape back to feature map

        # Decoder
        x = F.leaky_relu(self.bn6(self.dec1(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn7(self.dec2(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn8(self.dec3(x)), negative_slope=0.01)
        x = F.leaky_relu(self.bn9(self.dec4(x)), negative_slope=0.01)
        x = torch.sigmoid(self.dec5(x))  # Sigmoid for output (0-1
pixel values)

        return x


model = ConvAutoencoder()

summary(model,input_size=(32,3,128,128))
```

```
==========================================================================
====================
Layer (type:depth-idx)                   Output Shape
Param #
==========================================================================
====================
ConvAutoencoder                          [32, 3, 128, 128]         --
├─Conv2d: 1-1                            [32, 64, 64, 64]
1,792
├─BatchNorm2d: 1-2                       [32, 64, 64, 64]          128
├─Conv2d: 1-3                            [32, 128, 32, 32]
73,856
├─BatchNorm2d: 1-4                       [32, 128, 32, 32]         256
├─Conv2d: 1-5                            [32, 256, 16, 16]
295,168
```

```
├─BatchNorm2d: 1-6                       [32, 256, 16, 16]         512
├─Conv2d: 1-7                            [32, 512, 8, 8]
1,180,160
├─BatchNorm2d: 1-8                       [32, 512, 8, 8]
1,024
├─Conv2d: 1-9                            [32, 1024, 4, 4]
4,719,616
├─BatchNorm2d: 1-10                      [32, 1024, 4, 4]
2,048
├─Linear: 1-11                           [32, 2048]
33,556,480
├─Dropout: 1-12                          [32, 2048]                --
├─Linear: 1-13                           [32, 16384]
33,570,816
├─ConvTranspose2d: 1-14                  [32, 512, 8, 8]
4,719,104
├─BatchNorm2d: 1-15                      [32, 512, 8, 8]
1,024
├─ConvTranspose2d: 1-16                  [32, 256, 16, 16]
1,179,904
├─BatchNorm2d: 1-17                      [32, 256, 16, 16]         512
├─ConvTranspose2d: 1-18                  [32, 128, 32, 32]
295,040
├─BatchNorm2d: 1-19                      [32, 128, 32, 32]         256
├─ConvTranspose2d: 1-20                  [32, 64, 64, 64]
73,792
├─BatchNorm2d: 1-21                      [32, 64, 64, 64]          128
├─ConvTranspose2d: 1-22                  [32, 3, 128, 128]
1,731
==========================================================================
====================
Total params: 79,673,347
Trainable params: 79,673,347
Non-trainable params: 0
Total mult-adds (G): 51.63
==========================================================================
====================
Input size (MB): 6.29
Forward/backward pass size (MB): 529.01
Params size (MB): 318.69
Estimated Total Size (MB): 853.99
==========================================================================
====================
```

Define Constants and Prepare the Data

```
NUM_EPOCHS = 100
LEARNING_RATE = 5e-5
```

```
criterion = nn.MSELoss()
optimizer = optim.Adam(model.parameters(), lr=LEARNING_RATE)
```

Train and Test Functions

```
def train(net, trainloader, valloader, num_epochs, optimizer,
criterion, device):
    train_loss = []
    val_loss = []

    # Initialize ReduceLROnPlateau scheduler
    scheduler = torch.optim.lr_scheduler.ReduceLROnPlateau(optimizer,
mode='min', factor=0.5, patience=3, verbose=True, min_lr=1e-6)

    # Early stopping parameters
    best_val_loss = float('inf')
    patience = 5  # Number of epochs to wait before stopping
    patience_counter = 0
    early_stop = False

    for epoch in range(num_epochs):
        if early_stop:
            print("Early stopping triggered.")
            break

        net.train()
        running_train_loss = 0.0
        for data in tqdm(trainloader, desc=f"Training Epoch
{epoch+1}/{num_epochs}", unit="batch"):
            img, _ = data
            img = img.to(device)

            optimizer.zero_grad()
            outputs = net(img)
            loss = criterion(outputs, img)
            loss.backward()
            optimizer.step()
            running_train_loss += loss.item()

        avg_train_loss = running_train_loss / len(trainloader)
        train_loss.append(avg_train_loss)

        net.eval()
        running_val_loss = 0.0
        with torch.no_grad():
            for data in tqdm(valloader, desc=f"Validation Epoch
{epoch+1}/{num_epochs}", unit="batch"):
```

```
                img, _ = data
                img = img.to(device)

                outputs = net(img)
                loss = criterion(outputs, img)
                running_val_loss += loss.item()

        avg_val_loss = running_val_loss / len(valloader)
        val_loss.append(avg_val_loss)

        print(tabulate([['Epoch', epoch+1, 'Train Loss',
f'{avg_train_loss:.3f}', 'Val Loss', f'{avg_val_loss:.3f}']],
                       headers=['Metric', 'Value', 'Metric', 'Value',
'Metric', 'Value'], tablefmt='grid'))

        # Step the scheduler based on validation loss
        scheduler.step(avg_val_loss)

        # Early stopping logic
        if avg_val_loss < best_val_loss:
            best_val_loss = avg_val_loss
            patience_counter = 0  # Reset counter if validation loss
improves
            # Optionally save the best model
            torch.save(net.state_dict(), 'best_model.pth')
        else:
            patience_counter += 1
            print(f"Validation loss did not improve. Patience counter:
{patience_counter}/{patience}")
            if patience_counter >= patience:
                early_stop = True

        if (epoch + 1) % 5 == 0:
            save_decoded_image(outputs.cpu().data, epoch + 1)

    return train_loss, val_loss

def test_image_reconstruction(net, testloader, device):
    for batch in tqdm(testloader, desc="Testing", unit="batch"):
        img, _ = batch
        img = img.to(device)

        outputs = net(img)
        outputs = outputs.view(outputs.size(0), 3, 128,
128).cpu().data  # Fixed to match model output

        save_image(outputs, 'monkey_reconstruction.png')
        break

# Assuming model, train_loader, valid_loader, optimizer, criterion,
```

```
and NUM_EPOCHS are defined
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
model.to(device)

num_epochs = NUM_EPOCHS  # Assuming this is defined elsewhere

make_dir()
print("Training the model...")
train_loss, val_loss = train(model, train_loader, valid_loader,
num_epochs, optimizer, criterion, device)
```

```
/usr/local/lib/python3.10/dist-packages/torch/optim/
lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated.
Please use get_last_lr() to access the learning rate.
  warnings.warn(

Training the model...

Training Epoch 1/100: 100%|██████████| 35/35 [00:24<00:00,
1.45batch/s]
Validation Epoch 1/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       1 | Train Loss |   0.687 | Val Loss |   0.661 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 2/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 2/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       2 | Train Loss |   0.598 | Val Loss |    0.58 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 3/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 3/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       3 | Train Loss |   0.536 | Val Loss |   0.514 |
+----------+---------+------------+---------+----------+---------+
```

```
Training Epoch 4/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 4/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       4 | Train Loss |   0.504 | Val Loss |   0.508 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 5/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 5/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       5 | Train Loss |   0.475 | Val Loss |   0.473 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 6/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 6/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       6 | Train Loss |   0.458 | Val Loss |   0.469 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 7/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 7/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       7 | Train Loss |   0.442 | Val Loss |   0.451 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 8/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 8/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
```

```
+==========+=========+============+=========+==========+=========+
| Epoch    |       8 | Train Loss |   0.425 | Val Loss |   0.429 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 9/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 9/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |       9 | Train Loss |   0.412 | Val Loss |   0.409 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 10/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 10/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      10 | Train Loss |   0.398 | Val Loss |   0.399 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 11/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 11/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      11 | Train Loss |   0.386 | Val Loss |   0.381 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 12/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 12/100: 100%|██████████| 9/9 [00:06<00:00,
1.41batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      12 | Train Loss |   0.378 | Val Loss |   0.375 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 13/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
```

```
Validation Epoch 13/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      13 | Train Loss |   0.369 | Val Loss |   0.358 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 14/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 14/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      14 | Train Loss |    0.36 | Val Loss |   0.356 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 15/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 15/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      15 | Train Loss |   0.351 | Val Loss |   0.351 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 16/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 16/100: 100%|██████████| 9/9 [00:06<00:00,
1.42batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      16 | Train Loss |   0.346 | Val Loss |   0.345 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 17/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 17/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
```

```
| Epoch    |      17 | Train Loss |    0.34 | Val Loss |    0.34 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 18/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 18/100: 100%|██████████| 9/9 [00:06<00:00,
1.40batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      18 | Train Loss |   0.332 | Val Loss |   0.328 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 19/100: 100%|██████████| 35/35 [00:24<00:00,
1.43batch/s]
Validation Epoch 19/100: 100%|██████████| 9/9 [00:06<00:00,
1.36batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      19 | Train Loss |   0.328 | Val Loss |   0.326 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 20/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 20/100: 100%|██████████| 9/9 [00:06<00:00,
1.42batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      20 | Train Loss |   0.322 | Val Loss |   0.322 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 21/100: 100%|██████████| 35/35 [00:24<00:00,
1.45batch/s]
Validation Epoch 21/100: 100%|██████████| 9/9 [00:06<00:00,
1.41batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      21 | Train Loss |   0.318 | Val Loss |   0.318 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 22/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 22/100: 100%|██████████| 9/9 [00:06<00:00,
1.40batch/s]
```

```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      22 | Train Loss |   0.312 | Val Loss |   0.307 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 23/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 23/100: 100%|██████████| 9/9 [00:06<00:00,
1.42batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      23 | Train Loss |   0.308 | Val Loss |   0.307 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 24/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 24/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      24 | Train Loss |   0.304 | Val Loss |   0.304 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 25/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 25/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      25 | Train Loss |     0.3 | Val Loss |   0.303 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 26/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 26/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      26 | Train Loss |   0.299 | Val Loss |   0.301 |
+----------+---------+------------+---------+----------+---------+
```

```
Training Epoch 27/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 27/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      27 | Train Loss |   0.295 | Val Loss |   0.298 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 28/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 28/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      28 | Train Loss |   0.292 | Val Loss |   0.293 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 29/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 29/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      29 | Train Loss |   0.288 | Val Loss |   0.292 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 30/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 30/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      30 | Train Loss |   0.285 | Val Loss |   0.289 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 31/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 31/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
```

```
+==========+=========+============+=========+==========+=========+
| Epoch    |      31 | Train Loss |   0.284 | Val Loss |   0.283 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 32/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 32/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      32 | Train Loss |   0.283 | Val Loss |   0.287 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 33/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 33/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      33 | Train Loss |    0.28 | Val Loss |   0.286 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 34/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 34/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      34 | Train Loss |   0.277 | Val Loss |    0.28 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 35/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 35/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      35 | Train Loss |   0.275 | Val Loss |    0.28 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5
```

```
Training Epoch 36/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 36/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      36 | Train Loss |   0.272 | Val Loss |   0.276 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 37/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 37/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      37 | Train Loss |   0.272 | Val Loss |   0.277 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 38/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 38/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      38 | Train Loss |   0.269 | Val Loss |   0.273 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 39/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 39/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      39 | Train Loss |   0.269 | Val Loss |   0.275 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 40/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 40/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]
```

```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      40 | Train Loss |   0.267 | Val Loss |   0.275 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 41/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 41/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      41 | Train Loss |   0.266 | Val Loss |   0.271 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 42/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 42/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      42 | Train Loss |   0.264 | Val Loss |   0.273 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 43/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 43/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      43 | Train Loss |   0.265 | Val Loss |   0.272 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 44/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 44/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
```

```
| Epoch    |      44 | Train Loss |   0.263 | Val Loss |   0.267 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 45/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 45/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      45 | Train Loss |   0.258 | Val Loss |   0.266 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 46/100: 100%|██████████| 35/35 [00:24<00:00,
1.44batch/s]
Validation Epoch 46/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      46 | Train Loss |   0.257 | Val Loss |   0.264 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 47/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 47/100: 100%|██████████| 9/9 [00:06<00:00,
1.36batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      47 | Train Loss |   0.258 | Val Loss |   0.265 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 48/100: 100%|██████████| 35/35 [00:24<00:00,
1.42batch/s]
Validation Epoch 48/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      48 | Train Loss |   0.257 | Val Loss |   0.263 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 49/100: 100%|██████████| 35/35 [00:24<00:00,
1.45batch/s]
```

```
Validation Epoch 49/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      49 | Train Loss |   0.256 | Val Loss |   0.263 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 50/100: 100%|██████████| 35/35 [00:24<00:00,
1.44batch/s]
Validation Epoch 50/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      50 | Train Loss |   0.254 | Val Loss |   0.262 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 51/100: 100%|██████████| 35/35 [00:24<00:00,
1.45batch/s]
Validation Epoch 51/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      51 | Train Loss |   0.253 | Val Loss |   0.262 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 52/100: 100%|██████████| 35/35 [00:24<00:00,
1.44batch/s]
Validation Epoch 52/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      52 | Train Loss |   0.254 | Val Loss |   0.261 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 53/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 53/100: 100%|██████████| 9/9 [00:06<00:00,
1.41batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
```

```
| Epoch    |      53 | Train Loss |   0.252 | Val Loss |    0.26 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 54/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 54/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      54 | Train Loss |   0.253 | Val Loss |    0.26 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 55/100: 100%|██████████| 35/35 [00:24<00:00,
1.45batch/s]
Validation Epoch 55/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      55 | Train Loss |    0.25 | Val Loss |   0.258 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 56/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 56/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      56 | Train Loss |   0.248 | Val Loss |   0.258 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 57/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 57/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      57 | Train Loss |   0.248 | Val Loss |   0.258 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 58/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 58/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]
```

```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      58 | Train Loss |   0.247 | Val Loss |   0.255 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 59/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 59/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      59 | Train Loss |   0.246 | Val Loss |   0.254 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 60/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 60/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      60 | Train Loss |   0.244 | Val Loss |   0.254 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 61/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 61/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      61 | Train Loss |   0.245 | Val Loss |   0.255 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 62/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 62/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      62 | Train Loss |   0.243 | Val Loss |   0.253 |
+----------+---------+------------+---------+----------+---------+
```

```
Training Epoch 63/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 63/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      63 | Train Loss |   0.244 | Val Loss |   0.254 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 64/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 64/100: 100%|██████████| 9/9 [00:06<00:00,
1.40batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      64 | Train Loss |   0.243 | Val Loss |   0.252 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 65/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 65/100: 100%|██████████| 9/9 [00:06<00:00,
1.38batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      65 | Train Loss |   0.243 | Val Loss |   0.251 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 66/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 66/100: 100%|██████████| 9/9 [00:06<00:00,
1.40batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      66 | Train Loss |   0.241 | Val Loss |   0.252 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 67/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 67/100: 100%|██████████| 9/9 [00:06<00:00,
1.39batch/s]
```

```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      67 | Train Loss |   0.241 | Val Loss |   0.254 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 68/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 68/100: 100%|██████████| 9/9 [00:06<00:00,
1.42batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      68 | Train Loss |   0.241 | Val Loss |   0.251 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 69/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 69/100: 100%|██████████| 9/9 [00:06<00:00,
1.41batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      69 | Train Loss |    0.24 | Val Loss |    0.25 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 70/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 70/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      70 | Train Loss |   0.238 | Val Loss |    0.25 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 71/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 71/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      71 | Train Loss |    0.24 | Val Loss |    0.25 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5
```

```
Training Epoch 72/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 72/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      72 | Train Loss |   0.236 | Val Loss |   0.248 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 73/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 73/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      73 | Train Loss |   0.236 | Val Loss |   0.248 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 74/100: 100%|██████████| 35/35 [00:23<00:00,
1.46batch/s]
Validation Epoch 74/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      74 | Train Loss |   0.235 | Val Loss |   0.247 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 75/100: 100%|██████████| 35/35 [00:24<00:00,
1.44batch/s]
Validation Epoch 75/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      75 | Train Loss |   0.236 | Val Loss |   0.248 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 76/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 76/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]
```

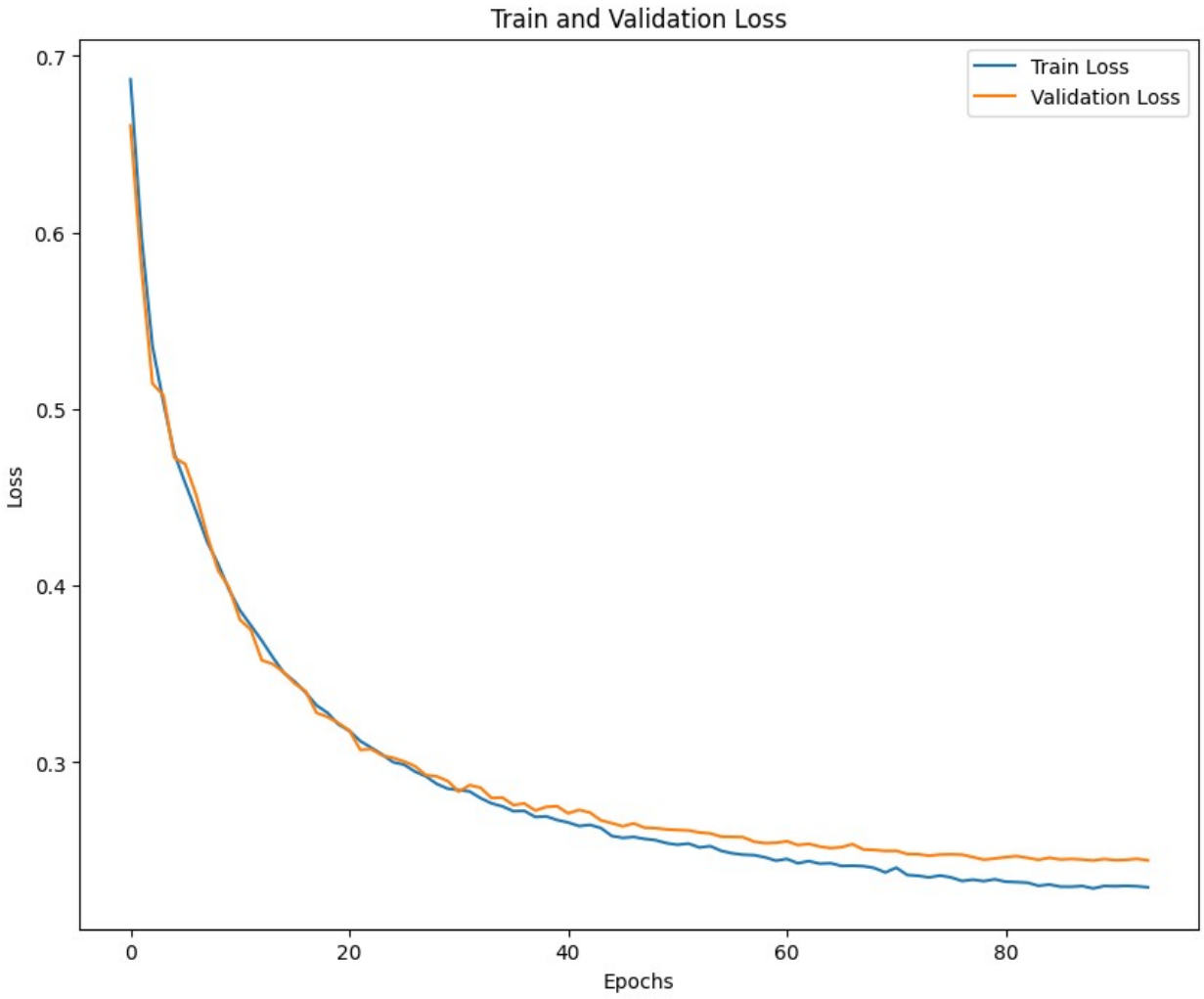
```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      76 | Train Loss |   0.235 | Val Loss |   0.248 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 77/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 77/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      77 | Train Loss |   0.233 | Val Loss |   0.248 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 3/5

Training Epoch 78/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 78/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      78 | Train Loss |   0.234 | Val Loss |   0.246 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 79/100: 100%|██████████| 35/35 [00:24<00:00,
1.46batch/s]
Validation Epoch 79/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      79 | Train Loss |   0.233 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 80/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 80/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      80 | Train Loss |   0.234 | Val Loss |   0.246 |
```

```
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 81/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 81/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      81 | Train Loss |   0.232 | Val Loss |   0.246 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 82/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 82/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      82 | Train Loss |   0.232 | Val Loss |   0.247 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 3/5

Training Epoch 83/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 83/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      83 | Train Loss |   0.232 | Val Loss |   0.246 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 4/5

Training Epoch 84/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 84/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      84 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
```

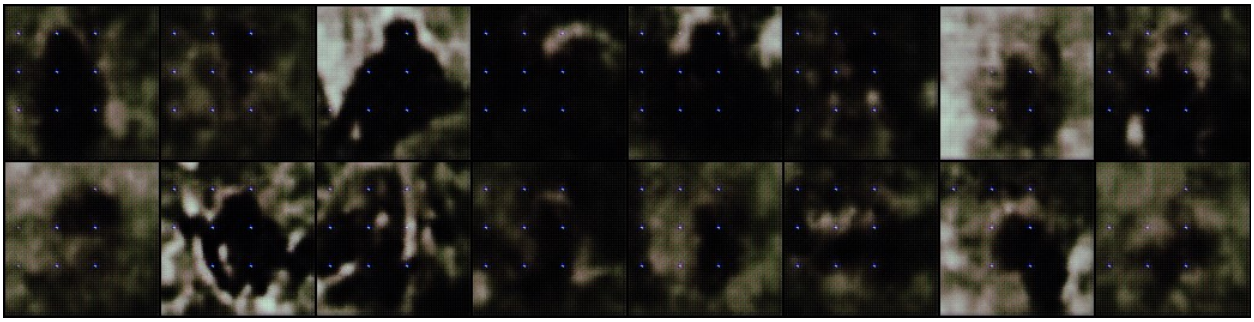
```
Training Epoch 85/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 85/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      85 | Train Loss |   0.231 | Val Loss |   0.246 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 86/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 86/100: 100%|██████████| 9/9 [00:06<00:00,
1.47batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      86 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 87/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 87/100: 100%|██████████| 9/9 [00:06<00:00,
1.48batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      87 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 3/5

Training Epoch 88/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 88/100: 100%|██████████| 9/9 [00:06<00:00,
1.48batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      88 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 4/5

Training Epoch 89/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
```

```
Validation Epoch 89/100: 100%|██████████| 9/9 [00:06<00:00,
1.45batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      89 | Train Loss |   0.229 | Val Loss |   0.244 |
+----------+---------+------------+---------+----------+---------+

Training Epoch 90/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 90/100: 100%|██████████| 9/9 [00:06<00:00,
1.46batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      90 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 1/5

Training Epoch 91/100: 100%|██████████| 35/35 [00:23<00:00,
1.48batch/s]
Validation Epoch 91/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      91 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 2/5

Training Epoch 92/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 92/100: 100%|██████████| 9/9 [00:06<00:00,
1.44batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      92 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 3/5

Training Epoch 93/100: 100%|██████████| 35/35 [00:23<00:00,
1.47batch/s]
Validation Epoch 93/100: 100%|██████████| 9/9 [00:06<00:00,
1.38batch/s]
```

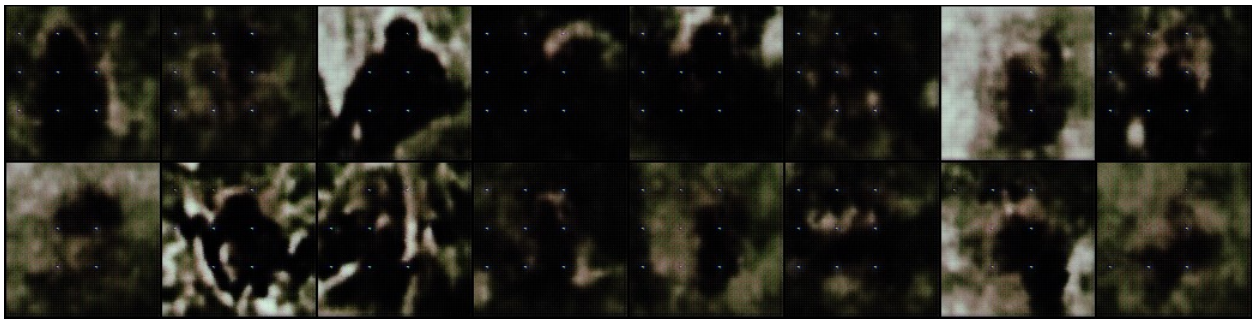
```
+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      93 | Train Loss |    0.23 | Val Loss |   0.245 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 4/5

Training Epoch 94/100: 100%|██████████| 35/35 [00:23<00:00,
1.49batch/s]
Validation Epoch 94/100: 100%|██████████| 9/9 [00:06<00:00,
1.43batch/s]

+----------+---------+------------+---------+----------+---------+
| Metric   |   Value | Metric     |   Value | Metric   |   Value |
+==========+=========+============+=========+==========+=========+
| Epoch    |      94 | Train Loss |   0.229 | Val Loss |   0.244 |
+----------+---------+------------+---------+----------+---------+
Validation loss did not improve. Patience counter: 5/5
Early stopping triggered.



plt.figure(figsize=(10,8))
plt.plot(train_loss, label='Train Loss')
plt.plot(val_loss, label='Validation Loss')
plt.title('Train and Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.savefig('train_val_loss.png')

print("Testing the model...")
test_image_reconstruction(model, valid_loader, device)

Testing the model...

Testing:   0%|          | 0/9 [00:01<?, ?batch/s]
```




```
from IPython.display import Image

Image('/kaggle/working/Monkey_Images/linear_ae_image50.png')
```



```
Image('/kaggle/working/Monkey_Images/linear_ae_image60.png')
```



```
Image('/kaggle/working/Monkey_Images/linear_ae_image90.png')
```

Reconstructed Images

```
Image("/kaggle/working/monkey_reconstruction.png")
```

Original Images

```
import numpy as np

def imshow(img):
    npimg = img.numpy()
    plt.figure(figsize=(20, 12))
    plt.imshow(np.transpose(npimg, (1, 2, 0)))
    plt.show()

# Get some random training images
dataiter = iter(train_loader)
images, labels = next(dataiter)  # Use next() instead of
dataiter.next()

# Show images
imshow(torchvision.utils.make_grid(images))
```