```
!pip install imageio
!pip install matplotlib
!pip install ipywidgets
!pip install tqdm
```

```
Requirement already satisfied: imageio in c:\users\sc23gd\.conda\envs\
pytorch\lib\site-packages (2.34.1)
Requirement already satisfied: numpy in c:\users\sc23gd\.conda\envs\
pytorch\lib\site-packages (from imageio) (1.24.3)
Requirement already satisfied: pillow>=8.3.2 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from imageio) (10.3.0)
Requirement already satisfied: matplotlib in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (3.9.0)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib) (1.2.1)
Requirement already satisfied: cycler>=0.10 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib)
(4.53.0)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib) (1.4.5)
Requirement already satisfied: numpy>=1.23 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from matplotlib) (1.24.3)
Requirement already satisfied: packaging>=20.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib) (24.1)
Requirement already satisfied: pillow>=8 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from matplotlib) (10.3.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from matplotlib) (2.9.0)
Requirement already satisfied: six>=1.5 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from python-dateutil>=2.7->matplotlib)
(1.16.0)
Requirement already satisfied: ipywidgets in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (8.1.3)
Requirement already satisfied: comm>=0.1.3 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from ipywidgets) (0.2.2)
Requirement already satisfied: ipython>=6.1.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipywidgets)
(8.25.0)
Requirement already satisfied: traitlets>=4.3.1 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipywidgets)
(5.14.3)
Requirement already satisfied: widgetsnbextension~=4.0.11 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipywidgets)
(4.0.11)
Requirement already satisfied: jupyterlab-widgets~=3.0.11 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipywidgets)
```

```
(3.0.11)
Requirement already satisfied: decorator in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from ipython>=6.1.0->ipywidgets)
(5.1.1)
Requirement already satisfied: jedi>=0.16 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from ipython>=6.1.0->ipywidgets)
(0.19.1)
Requirement already satisfied: matplotlib-inline in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipython>=6.1.0-
>ipywidgets) (0.1.7)
Requirement already satisfied: prompt-toolkit<3.1.0,>=3.0.41 in c:\
users\sc23gd\.conda\envs\pytorch\lib\site-packages (from
ipython>=6.1.0->ipywidgets) (3.0.47)
Requirement already satisfied: pygments>=2.4.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipython>=6.1.0-
>ipywidgets) (2.18.0)
Requirement already satisfied: stack-data in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from ipython>=6.1.0->ipywidgets)
(0.6.2)
Requirement already satisfied: typing-extensions>=4.6 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from ipython>=6.1.0-
>ipywidgets) (4.11.0)
Requirement already satisfied: colorama in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from ipython>=6.1.0->ipywidgets)
(0.4.6)
Requirement already satisfied: parso<0.9.0,>=0.8.3 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from jedi>=0.16-
>ipython>=6.1.0->ipywidgets) (0.8.4)
Requirement already satisfied: wcwidth in c:\users\sc23gd\.conda\envs\
pytorch\lib\site-packages (from prompt-toolkit<3.1.0,>=3.0.41-
>ipython>=6.1.0->ipywidgets) (0.2.13)
Requirement already satisfied: executing>=1.2.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from stack-data-
>ipython>=6.1.0->ipywidgets) (2.0.1)
Requirement already satisfied: asttokens>=2.1.0 in c:\users\
sc23gd\.conda\envs\pytorch\lib\site-packages (from stack-data-
>ipython>=6.1.0->ipywidgets) (2.4.1)
Requirement already satisfied: pure-eval in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from stack-data->ipython>=6.1.0-
>ipywidgets) (0.2.2)
Requirement already satisfied: six>=1.12.0 in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from asttokens>=2.1.0->stack-data-
>ipython>=6.1.0->ipywidgets) (1.16.0)
Collecting tqdm
  Using cached tqdm-4.66.4-py3-none-any.whl.metadata (57 kB)
Requirement already satisfied: colorama in c:\users\sc23gd\.conda\
envs\pytorch\lib\site-packages (from tqdm) (0.4.6)
Downloading tqdm-4.66.4-py3-none-any.whl (78 kB)
   ---------------------------------------- 0.0/78.3 kB ? eta -:--:--
```

```
   -------------- ------------------------ 30.7/78.3 kB 660.6 kB/s
eta 0:00:01
   ---------------------------------------- 78.3/78.3 kB 1.1 MB/s eta
0:00:00
Installing collected packages: tqdm
Successfully installed tqdm-4.66.4
```

```
import torch
import torch.nn as nn
import torch.optim as optim
import torch.distributed as dist
from torch.nn.parallel import DistributedDataParallel as DDP
from torch.utils.data import DataLoader, DistributedSampler,
TensorDataset
import numpy as np
import io
import imageio
import matplotlib.pyplot as plt
from IPython.display import Image, display
from ipywidgets import widgets, Layout, HBox
from torch.utils.data import TensorDataset, DataLoader
from torchvision.datasets.utils import download_url
import random

from torch.utils.tensorboard import SummaryWriter

writer = SummaryWriter('runs/conv_ae_experiment')

# Downloading the Moving MNIST dataset
url =
"http://www.cs.toronto.edu/~nitish/unsupervised_video/mnist_test_seq.n
py"
fpath = "moving_mnist.npy"
download_url(url, root=".", filename=fpath)
dataset = np.load(fpath)

# Swapping the axes representing the number of frames and number of
data samples
dataset = np.swapaxes(dataset, 0, 1)

# We pick out 1000 of the 10000 total examples and use those
dataset = dataset[:5000, ...]

# Adding a channel dimension since the images are grayscale
dataset = np.expand_dims(dataset, axis=-1)

# Splitting into train and validation sets using indexing to optimize
memory
indexes = np.arange(dataset.shape[0])
np.random.shuffle(indexes)
train_index = indexes[: int(0.9 * dataset.shape[0])]
```

```
val_index = indexes[int(0.9 * dataset.shape[0]) :]
train_dataset = dataset[train_index]
val_dataset = dataset[val_index]

'''
# Normalizing the data to the 0-1 range
train_dataset = train_dataset / 255
val_dataset = val_dataset / 255

'''

#normalizing the data to have zero mean and unit variance
mean = train_dataset.mean()
std = train_dataset.std()
train_dataset = (train_dataset - mean) / std
val_dataset = (val_dataset - mean) / std


# We define a helper function to shift the frames, where
# 'x' is frame 0 to n - 1, and 'y' is frames 1 to n
def create_shifted_frames(data):
    x = data[:, 0 : data.shape[1] - 1, :, :]
    y = data[:, 1 : data.shape[1], :, :]
    return x, y

# Apply the processing function to the datasets
x_train, y_train = create_shifted_frames(train_dataset)
x_val, y_val = create_shifted_frames(val_dataset)

# Convert numpy arrays to PyTorch tensors
x_train = torch.from_numpy(x_train).float()
y_train = torch.from_numpy(y_train).float()
x_val = torch.from_numpy(x_val).float()
y_val = torch.from_numpy(y_val).float()

# Create TensorDataset and DataLoader
train_dataset = TensorDataset(x_train, y_train)
val_dataset = TensorDataset(x_val, y_val)

batch_size = 64
train_loader = DataLoader(train_dataset, batch_size=batch_size,
shuffle=True, num_workers=20)
val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False, num_workers=20)

# Inspect the dataset
print("Training Dataset Shapes: " + str(x_train.shape) + ", " +
str(y_train.shape))
print("Validation Dataset Shapes: " + str(x_val.shape) + ", " +
str(y_val.shape))
```

```
Using downloaded and verified file: .\moving_mnist.npy
Training Dataset Shapes: torch.Size([4500, 19, 64, 64, 1]),
torch.Size([4500, 19, 64, 64, 1])
Validation Dataset Shapes: torch.Size([500, 19, 64, 64, 1]),
torch.Size([500, 19, 64, 64, 1])
```

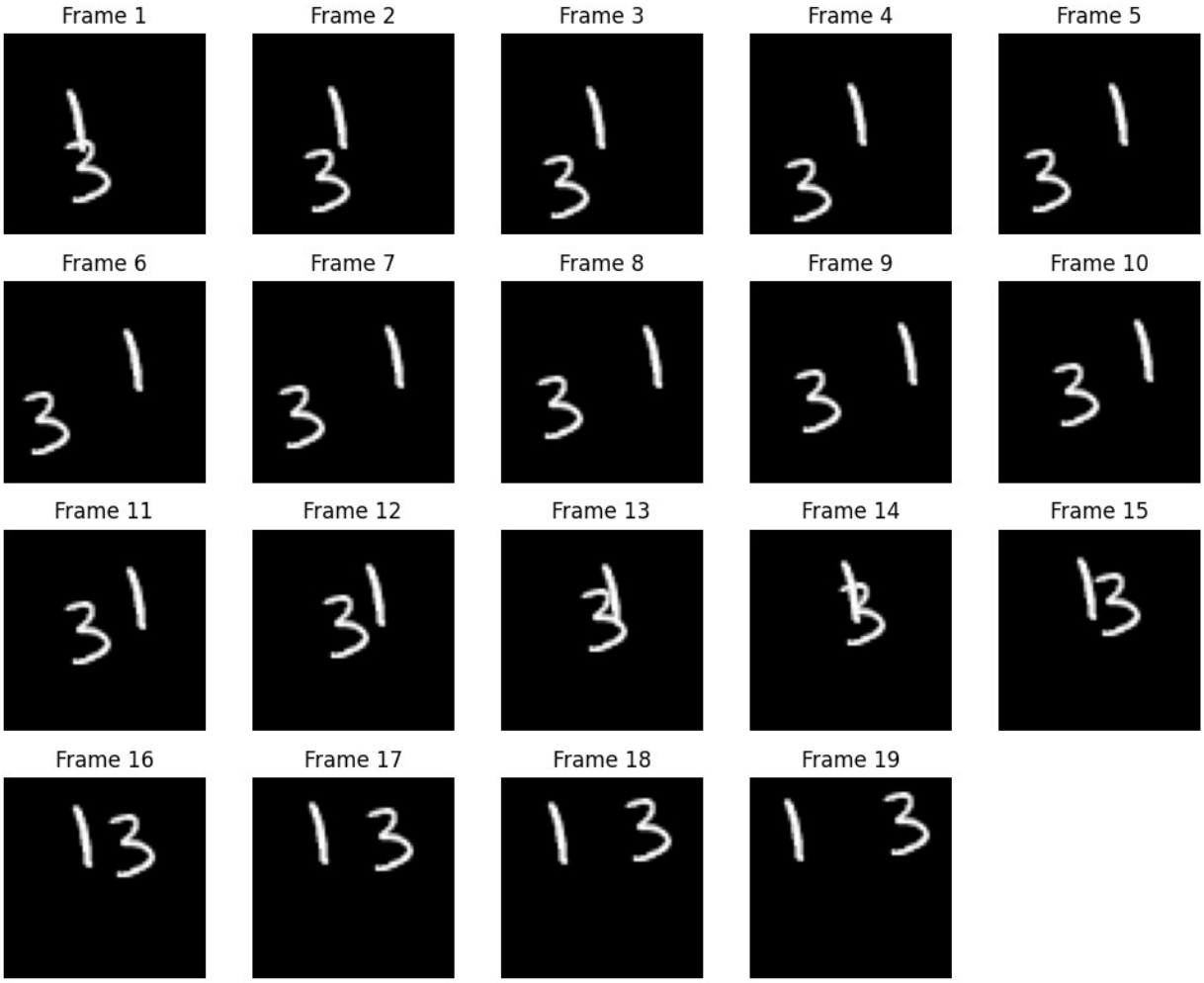
```
# Construct a figure on which we will visualize the images
fig, axes = plt.subplots(4, 5, figsize=(10, 8))

# Plot each of the sequential images for one random data example
data_choice = np.random.choice(range(len(train_dataset)), size=1)[0]
frames = train_dataset.tensors[0][data_choice]

for idx, ax in enumerate(axes.flat):
    if idx < frames.shape[0]:
        frame = frames[idx].squeeze().numpy()
        ax.imshow(frame, cmap="gray")
        ax.set_title(f"Frame {idx + 1}")
        ax.axis("off")
    else:
        ax.axis("off")

# Print information and display the figure
print(f"Displaying frames for example {data_choice}.")
plt.tight_layout()
plt.show()
```

```
Displaying frames for example 1923.
```




```
# Define the Encoder module
class Encoder(nn.Module):
    def __init__(self, input_shape, latent_dim):
        super(Encoder, self).__init__()
        self.conv1 = nn.Conv3d(input_shape[3], 128, kernel_size=(3, 5,
5), padding=(1, 2, 2), stride=(1, 2, 2))
        self.bn1 = nn.BatchNorm3d(128)
        self.conv2 = nn.Conv3d(128, 256, kernel_size=(3, 3, 3),
padding=(1, 1, 1), stride=(1, 2, 2))
        self.bn2 = nn.BatchNorm3d(256)
        self.conv3 = nn.Conv3d(256, 512, kernel_size=(3, 3, 3),
padding=(1, 1, 1), stride=(1, 2, 2))
        self.bn3 = nn.BatchNorm3d(512)
        self.flatten = nn.Flatten()
        self.dense1 = nn.Linear(512 * input_shape[0] * input_shape[1]
// 8 * input_shape[2] // 8, latent_dim)

    def forward(self, x):
        x = x.permute(0, 4, 1, 2, 3)  # Rearrange dimensions to
```

```
(batch_size, channels, frames, height, width)
        x = torch.relu(self.bn1(self.conv1(x)))
        x = torch.relu(self.bn2(self.conv2(x)))
        x = torch.relu(self.bn3(self.conv3(x)))
        x = self.flatten(x)
        z = self.dense1(x)
        return z

# Define the Decoder module
class Decoder(nn.Module):
    def __init__(self, latent_dim, output_shape):
        super(Decoder, self).__init__()
        self.dense1 = nn.Linear(latent_dim, 512 * output_shape[0] *
output_shape[1] // 8 * output_shape[2] // 8)
        self.unflatten = nn.Unflatten(dim=1, unflattened_size=(512,
output_shape[0], output_shape[1] // 8, output_shape[2] // 8))
        self.deconv1 = nn.ConvTranspose3d(512, 256, kernel_size=(3, 3,
3), padding=(1, 1, 1), stride=(1, 2, 2), output_padding=(0, 1, 1))
        self.bn1 = nn.BatchNorm3d(256)
        self.deconv2 = nn.ConvTranspose3d(256, 128, kernel_size=(3, 3,
3), padding=(1, 1, 1), stride=(1, 2, 2), output_padding=(0, 1, 1))
        self.bn2 = nn.BatchNorm3d(128)
        self.deconv3 = nn.ConvTranspose3d(128, output_shape[3],
kernel_size=(3, 3, 3), padding=(1, 1, 1), stride=(1, 2, 2),
output_padding=(0, 1, 1))

    def forward(self, z):
        z = self.dense1(z)
        z = self.unflatten(z)
        z = torch.relu(self.bn1(self.deconv1(z)))
        z = torch.relu(self.bn2(self.deconv2(z)))
        recon_x = torch.sigmoid(self.deconv3(z))
        recon_x = recon_x.permute(0, 2, 3, 4, 1)  # Rearrange
dimensions back to (batch_size, frames, height, width, channels)
        return recon_x

# Define the AE module
class AE(nn.Module):
    def __init__(self, input_shape, latent_dim):
        super(AE, self).__init__()
        self.encoder = Encoder(input_shape, latent_dim)
        self.decoder = Decoder(latent_dim, input_shape)

    def forward(self, x):
        z = self.encoder(x)
        recon_x = self.decoder(z)
        return recon_x

# Set up device
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
```

```
# Define the model
input_shape = x_train.shape[1:]
latent_dim = 10
model = AE(input_shape, latent_dim).to(device)

for name, param in model.named_parameters():
    if param.requires_grad:
        print(name, param.data)
```

```
encoder.conv1.weight tensor([[[[ 0.0285, -0.0742,  0.0167,  0.0849, -
0.0489],
          [-0.1114, -0.1008, -0.0854,  0.0285,  0.0681],
          [ 0.0774,  0.0038, -0.0474, -0.0264,  0.0476],
          [ 0.0423,  0.0711, -0.0374,  0.1122,  0.0588],
          [-0.0155,  0.0086, -0.0863,  0.0075,  0.0972]],

         [[ 0.0722,  0.0509,  0.0549, -0.1029, -0.0660],
          [ 0.0547, -0.0748,  0.0443, -0.0112, -0.1104],
          [ 0.0584, -0.0152, -0.0391,  0.1031,  0.0493],
          [-0.0249, -0.0175,  0.1012,  0.0199, -0.1114],
          [-0.0355,  0.0188, -0.0347,  0.1017,  0.0299]],

         [[-0.0949, -0.0037,  0.0915,  0.1138, -0.0831],
          [ 0.0069, -0.1143, -0.0468, -0.0854, -0.0762],
          [-0.0608, -0.0180, -0.0949,  0.0400,  0.1048],
          [-0.0114,  0.0988,  0.0547, -0.0753,  0.0365],
          [-0.0951,  0.0999,  0.0039, -0.0415, -0.0319]]],



        [[[-0.0259,  0.0919,  0.0369,  0.0269, -0.0804],
          [ 0.0203, -0.0704, -0.0186, -0.0295, -0.0601],
          [-0.0483,  0.0992,  0.0699, -0.1030,  0.1075],
          [ 0.0925,  0.0185,  0.0650,  0.0970,  0.0298],
          [ 0.0117,  0.0384, -0.0468,  0.0132, -0.0500]],

         [[ 0.0254,  0.1148, -0.0660, -0.0402, -0.0395],
          [ 0.1018, -0.0465,  0.0318, -0.0950,  0.0194],
          [-0.0306,  0.0428, -0.0154,  0.1019, -0.0950],
          [ 0.1148, -0.0186,  0.0077,  0.0368, -0.0396],
          [-0.0713,  0.0357, -0.0871,  0.0649,  0.1121]],

         [[-0.0629, -0.0603, -0.1071, -0.0022,  0.0776],
          [ 0.1120,  0.0600, -0.0654,  0.0398,  0.0428],
          [-0.0345,  0.0248, -0.0569,  0.0539,  0.1075],
          [-0.0097, -0.0865, -0.0756,  0.0948,  0.0064],
          [ 0.0004, -0.1122, -0.0027,  0.1109,  0.0965]]],



        [[[-0.0096, -0.0318, -0.0222, -0.0912, -0.0651],
```

```
           [-0.0245, -0.0149,  0.1149,  0.0009,  0.0378],
           [-0.0071, -0.0681, -0.0510,  0.0282,  0.0429],
           [ 0.0120,  0.0791,  0.1014, -0.0649, -0.0038],
           [ 0.0392,  0.0502,  0.0351,  0.0041,  0.0774]],

          [[-0.0473, -0.0602, -0.0217, -0.0134, -0.1039],
           [-0.0472, -0.1000,  0.0214, -0.0476,  0.0257],
           [ 0.0598,  0.0508,  0.1031,  0.0883, -0.0260],
           [-0.0014,  0.1111,  0.0744, -0.0266, -0.1048],
           [-0.0293, -0.0085,  0.0827,  0.0488, -0.0268]],

          [[-0.0786,  0.0605, -0.0253,  0.1016, -0.0085],
           [-0.0810, -0.1053, -0.0688,  0.0245,  0.0162],
           [-0.0109, -0.0830,  0.0749, -0.0383,  0.0768],
           [-0.1133,  0.0889, -0.0793, -0.0307,  0.0273],
           [ 0.0030,  0.0114, -0.0825,  0.0608,  0.1010]]],



        ...,



        [[[[ 0.0909, -0.0393,  0.1098, -0.0189,  0.0761],
           [-0.0301, -0.0497, -0.0434,  0.0753, -0.0699],
           [ 0.0938,  0.0683, -0.0678, -0.0097, -0.0140],
           [-0.0905, -0.0210,  0.0593, -0.0659, -0.0799],
           [-0.0013, -0.0065,  0.0135, -0.1086, -0.0478]],

          [[-0.0899, -0.0150, -0.1115,  0.1089,  0.0731],
           [ 0.0965,  0.0226,  0.0589, -0.0797,  0.0108],
           [-0.0004, -0.0872, -0.0767, -0.0057, -0.0053],
           [ 0.0040, -0.1039,  0.0060,  0.0119, -0.0683],
           [-0.0650,  0.0903,  0.0552,  0.0705,  0.0978]],

          [[-0.0370, -0.0685, -0.0338,  0.0207, -0.0497],
           [-0.0340,  0.0653, -0.0241,  0.1060, -0.0673],
           [ 0.0452,  0.0030,  0.0038,  0.1131,  0.0906],
           [ 0.1104, -0.0128,  0.1041,  0.0661,  0.0748],
           [-0.0793, -0.0426,  0.0600,  0.0970,  0.1075]]]],



        [[[[ 0.0098,  0.1153, -0.1034, -0.0616,  0.0176],
           [-0.0969, -0.0517, -0.0135,  0.0030,  0.0411],
           [ 0.0782, -0.0268, -0.0728,  0.1080, -0.1092],
           [ 0.0697, -0.0587,  0.0754,  0.0203,  0.0888],
           [ 0.0437, -0.0082,  0.0008,  0.0030,  0.0080]],

          [[ 0.1005,  0.0848,  0.0053,  0.0954, -0.0687],
           [ 0.0632, -0.0367,  0.1132,  0.0312,  0.0937],
```

```
           [ 0.1044,  0.0714,  0.0020, -0.0379, -0.0103],
           [-0.0571,  0.0965, -0.0218, -0.0626, -0.0812],
           [ 0.0464, -0.0430,  0.0178,  0.0731,  0.0411]],

          [[-0.1049,  0.0987,  0.0286, -0.0786, -0.0091],
           [-0.1117,  0.1007,  0.0450, -0.0633,  0.0489],
           [-0.0746, -0.0238, -0.0805, -0.0272, -0.0927],
           [ 0.0735, -0.0922,  0.0618, -0.1131,  0.0115],
           [-0.0598,  0.0306, -0.0218, -0.0487, -0.0889]]]],



        [[[[ 0.0299,  0.0082,  0.0386,  0.0946,  0.0683],
           [ 0.0076, -0.0829, -0.0720,  0.0856,  0.1144],
           [-0.0568,  0.0889,  0.0773,  0.1077,  0.0699],
           [-0.0517,  0.0218,  0.0912,  0.0531,  0.0914],
           [ 0.0099,  0.0655, -0.0843,  0.0198,  0.0621]],

          [[ 0.0256,  0.0997,  0.1016,  0.0653,  0.0671],
           [ 0.0012, -0.1117, -0.0030,  0.0986, -0.0507],
           [-0.0334,  0.0908,  0.0392,  0.1110, -0.0554],
           [ 0.0762,  0.0832, -0.0597,  0.0365, -0.0157],
           [-0.0366,  0.0577,  0.0569,  0.0443, -0.0823]],

          [[-0.0130, -0.0563,  0.0632, -0.1076,  0.0302],
           [ 0.0212,  0.0490,  0.1098, -0.0652,  0.0694],
           [-0.0994,  0.0129,  0.0643, -0.0596, -0.0455],
           [ 0.0578, -0.0927, -0.0251, -0.1042,  0.0846],
           [-0.0510,  0.0389, -0.0085,  0.0318,  0.1143]]]],
device='cuda:0')
encoder.conv1.bias tensor([-0.0777,  0.0132,  0.1073, -0.0404,
0.0306,  0.0507, -0.0557, -0.0823,
         0.0005,  0.0723, -0.0329, -0.0172,  0.0263, -0.0754, -0.0346,
0.0525,
         0.0070,  0.0439, -0.0244, -0.0812, -0.0004,  0.0594, -0.0672,
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encoder.conv2.weight tensor([[[[[ 1.6771e-02,  3.0830e-03, -7.7243e-
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          [[ 9.9301e-03, -3.6241e-03,  8.7434e-03],
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        [ 1.2068e-03,  5.9576e-04,  7.9631e-04,  ...,  5.6941e-04,
         -2.3532e-04,  7.7976e-04],
        [-3.1988e-04,  9.8151e-04,  1.2660e-04,  ...,  4.4884e-04,
          9.6651e-04, -2.8450e-04],
        [ 2.3257e-04, -7.1437e-04, -1.0169e-03,  ...,  3.4063e-04,
          6.5818e-04, -1.1886e-03]], device='cuda:0')
encoder.dense1.bias tensor([ 0.0003,  0.0010, -0.0007,  0.0002, -
0.0013, -0.0006, -0.0002,  0.0009,
        -0.0004, -0.0005], device='cuda:0')
decoder.dense1.weight tensor([[ 0.0942, -0.2041,  0.1531,  ..., -
0.2018, -0.0254, -0.1348],
        [-0.0022, -0.0588,  0.2924,  ...,  0.0810,  0.2590,  0.1779],
        [ 0.1239,  0.2671,  0.0439,  ..., -0.0825,  0.2580, -0.0403],
```

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        ...,
        [ 0.3102, -0.0780, -0.2882,  ..., -0.2552, -0.0413,  0.0709],
        [-0.1193, -0.0171,  0.1109,  ..., -0.0971, -0.1170,  0.0055],
        [-0.2230, -0.0225,  0.1294,  ..., -0.0998, -0.2073, -0.1107]],
       device='cuda:0')
decoder.dense1.bias tensor([-0.1830, -0.1845, -0.2474,  ..., -0.1905,
0.0163,  0.1863],
       device='cuda:0')
decoder.deconv1.weight tensor([[[[-9.3808e-03, -3.1590e-03,  4.7807e-
04],
          [ 9.5542e-03, -1.0297e-02, -6.5439e-03],
          [ 8.6814e-03,  5.6202e-03, -1.0334e-02]],

         [[-1.1031e-02, -9.9073e-03,  8.0288e-03],
          [ 4.5933e-04,  4.7017e-03, -6.0970e-03],
          [-3.9555e-03,  5.4308e-03, -5.6672e-03]],

         [[ 1.1857e-02, -4.3006e-03, -9.4670e-03],
          [-1.0672e-02, -1.1682e-02, -6.1538e-03],
          [ 8.9572e-03, -9.2747e-03,  8.7036e-03]]],


        [[[-3.7028e-03,  1.1618e-02,  5.2930e-03],
          [ 1.0415e-02, -9.2975e-03, -1.1152e-02],
          [ 3.8895e-04, -1.4143e-04,  6.2639e-03]],

         [[-8.7217e-03,  1.0448e-02,  9.0136e-04],
          [ 1.0936e-03,  9.2516e-03,  4.0229e-03],
          [-5.6673e-03,  1.0125e-02,  2.8852e-03]],

         [[ 6.2128e-03,  6.9560e-03, -6.5214e-04],
          [-4.9747e-03,  5.9121e-03,  3.6476e-03],
          [ 1.1028e-02,  5.0826e-03,  1.1391e-02]]],


        [[[ 6.1645e-03,  1.1373e-02,  4.5521e-03],
          [ 1.0817e-03,  3.9547e-03,  9.8051e-03],
          [ 8.7311e-03,  1.0904e-02, -5.9867e-03]],

         [[-1.1958e-02, -3.8372e-03,  5.6758e-03],
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          [-1.7666e-03,  1.0508e-02,  1.8802e-03]],

         [[-1.0431e-02,  7.6937e-04,  9.8801e-03],
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          [ 8.8667e-03, -8.7874e-03,  4.8438e-03]]],


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         [[[-6.4663e-03, -1.1891e-02,  1.1639e-02],
           [-1.1805e-02,  3.5949e-03,  4.1406e-03],
           [-3.8419e-03, -5.6859e-03, -8.2809e-03]],

          [[-7.1518e-03, -3.5018e-03,  6.8755e-03],
           [-3.8185e-03,  3.7456e-03,  4.5850e-03],
           [-5.4439e-03,  9.7234e-03, -1.7869e-03]],

          [[ 1.1459e-02, -5.9251e-03, -3.1501e-03],
           [ 4.9539e-03,  7.1132e-03,  3.7154e-03],
           [-8.2527e-04,  1.0974e-02, -6.9893e-03]]],


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           [ 1.7268e-03,  2.8623e-03,  9.0059e-03],
           [-1.1755e-02, -1.2110e-03,  5.2473e-03]],

          [[ 8.8027e-03, -1.1006e-02,  2.3255e-03],
           [-1.0390e-02,  5.4489e-03, -9.1153e-03],
           [-8.6909e-04, -7.2497e-03,  8.4574e-03]],

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           [ 7.9192e-03, -6.1138e-03,  1.7759e-03]]],


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          [[-2.7739e-03, -2.2628e-03,  1.0177e-02],
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           [-5.8174e-03, -4.5400e-03,  2.5861e-03]],

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           [-2.5859e-03,  8.3304e-03, -5.3883e-03],
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        [[[[-4.9559e-03, -6.5778e-03, -4.7432e-04],
           [-2.9014e-03, -1.8216e-03,  4.2419e-03],
           [-9.2635e-03, -1.0210e-02, -6.3856e-03]],

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          [[-1.1955e-02,  9.7159e-03, -5.0884e-03],
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           [-6.0683e-03, -1.0452e-02,  5.8815e-03]]],
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         [[[ 4.6564e-03, -9.8720e-03, -2.6309e-04],
           [ 1.0377e-03,  2.3339e-03, -7.2644e-03],
           [-2.7343e-03,  9.2849e-03, -6.5244e-03]],

          [[ 7.9554e-03, -1.1375e-03, -9.8785e-03],
           [-7.1912e-03, -7.1638e-03,  2.9440e-03],
           [ 1.2181e-03,  3.2546e-03,  4.1619e-03]],

          [[ 1.1252e-02,  8.9882e-03,  1.4187e-03],
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           [-3.0730e-03,  7.3200e-03, -8.4074e-03]]],


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           [-8.1993e-03,  1.1383e-02,  7.7955e-03]],

          [[-8.4587e-03,  1.1454e-02,  9.8289e-03],
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         ...,


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           [-8.2660e-03,  1.0806e-02, -7.5854e-03]],

          [[-1.0839e-02, -7.1499e-03,  2.9232e-03],
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           [ 7.6724e-03, -1.2024e-02,  1.4245e-03]]],


         [[[ 9.4228e-03, -5.1780e-03, -1.1164e-02],
           [ 5.1538e-03, -6.1236e-03, -1.0958e-02],
           [-5.3823e-03, -5.5190e-03, -1.0670e-02]],

          [[ 7.0587e-03,  2.5895e-03,  1.1759e-02],
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           [ 4.7199e-03,  3.8887e-03, -1.8003e-04]],
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          [[-1.5555e-03, -2.7308e-03, -1.0411e-03],
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           [ 5.6172e-03,  6.5639e-03,  1.0712e-02]],

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          [[-1.2001e-02,  9.8959e-03, -8.7131e-03],
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          [[-6.9811e-03,  1.0721e-02,  5.8516e-03],
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           [ 1.1577e-02,  9.1932e-03,  1.1671e-03],
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           [ 1.5341e-03,  1.0665e-02,  9.0012e-03]]],


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          [[-8.7060e-03, -5.3922e-04, -1.4516e-03],
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          [[-1.1487e-02,  5.1718e-03, -1.4217e-03],
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           [ 9.6967e-03,  5.5642e-03,  6.4733e-03]],

          [[ 5.0792e-03, -1.1665e-02,  6.0764e-03],
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          [[-5.9906e-03,  8.3064e-03, -8.2023e-03],
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         [[[-2.4905e-03,  1.0970e-02, -6.1135e-03],
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           [-3.5617e-04,  6.9052e-03, -2.0507e-03]]],


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         [[[-1.0631e-02,  6.9879e-05, -7.4938e-03],
           [-2.6572e-03,  9.8879e-03, -1.2869e-03],
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           [ 1.1157e-02,  6.1686e-03,  1.0959e-02]],

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        [[[[ 6.9230e-05, -1.4642e-03,  9.7663e-03],
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          [[-6.5673e-03,  1.4365e-02, -5.4567e-03],
           [-3.3207e-03, -7.3995e-03, -9.7193e-03],
           [ 4.0871e-03, -1.0515e-02, -1.2573e-02]],

          [[-7.9696e-03, -7.6822e-03,  3.2899e-03],
           [ 8.2132e-03, -3.5238e-03, -2.0632e-03],
           [ 6.7573e-03, -6.8302e-03,  1.4742e-02]]],


         [[[ 1.2379e-02, -1.7497e-03, -5.8932e-04],
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           [-1.1568e-02,  3.8203e-03, -1.6932e-03]],

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         [[[-1.1024e-02,  1.3785e-02,  1.2154e-03],
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           [ 3.8816e-03, -1.3970e-02,  1.6408e-02]]],


         [[[-6.3671e-03, -1.4957e-02, -3.6695e-03],
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        -5.3649e-03, -8.8255e-03,  1.9746e-04, -5.3666e-03, -5.0722e-
03,
         3.2605e-03, -9.3545e-03, -8.8426e-03, -8.5455e-03, -8.9766e-
03,
        -6.5561e-03, -1.3467e-02, -9.6447e-03, -1.5880e-02,  6.1668e-
03,
```

```
        -1.6022e-02, -7.6147e-03, -7.3461e-03,  1.4590e-02, -8.2488e-
03,
         1.2200e-02,  9.1081e-03, -1.0903e-02, -6.9456e-03, -1.0602e-
02,
        -1.6965e-02,  1.2177e-02, -9.2198e-03, -1.2805e-02, -1.3949e-
02,
        -1.5872e-03,  3.5124e-03, -1.2103e-02, -3.6032e-03,  6.3375e-
03,
        -1.2598e-02,  6.8762e-03, -9.5395e-04,  4.1979e-03, -2.3147e-
03,
        -5.8450e-03,  2.7100e-03, -1.4354e-02, -6.3089e-03, -8.6891e-
03,
         1.9582e-03,  3.8609e-03, -1.4739e-02, -1.5138e-02,  5.6114e-
03,
         2.9044e-03,  9.0590e-04, -8.9091e-03, -1.1404e-02, -1.5318e-
02,
         9.7201e-03,  1.4169e-02,  1.1072e-02,  2.0886e-05, -1.4873e-
02,
        -4.5628e-03, -6.9204e-03,  1.4517e-03,  5.8626e-03, -2.9517e-
03,
        -1.0534e-02, -6.5110e-03,  1.4021e-02,  2.5968e-04, -6.3374e-
03,
        -9.8286e-03,  1.3706e-02, -7.1705e-03,  1.0262e-02,  1.4087e-
02,
         1.5326e-02,  6.3469e-03,  3.9436e-03,  9.7933e-03, -1.3005e-
02,
        -1.0889e-02, -4.8988e-03,  9.9443e-03,  1.3416e-02,  1.2032e-
02,
         1.5449e-02, -6.9413e-03,  1.0205e-02,  1.4329e-02, -3.4757e-
03,
        -8.0834e-03, -1.6212e-02, -7.9023e-03, -1.4205e-02, -9.6631e-
03,
         8.9333e-03, -1.7102e-03, -1.5769e-02, -8.2631e-03, -1.2463e-
02,
        -1.5520e-02, -1.6620e-02, -2.5872e-03,  1.5957e-02,  4.7779e-
03,
        -1.0893e-02, -4.7288e-03,  1.6984e-02], device='cuda:0')
decoder.bn2.weight tensor([1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1., 1., 1., 1., 1.,
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
```

```
        1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1., 1.,
1., 1., 1.,
        1., 1.], device='cuda:0')
decoder.bn2.bias tensor([0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
        0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
0., 0., 0., 0., 0., 0., 0., 0., 0.,
        0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
0., 0., 0., 0., 0., 0., 0., 0., 0.,
        0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
0., 0., 0., 0., 0., 0., 0., 0., 0.,
        0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
0., 0., 0., 0., 0., 0., 0., 0., 0.,
        0., 0., 0., 0., 0., 0., 0., 0.], device='cuda:0')
decoder.deconv3.weight tensor([[[[[ 0.1401,  0.0223, -0.0542],
           [-0.1515,  0.0493, -0.1015],
           [ 0.1066,  0.0753,  0.1341]],

          [[-0.1612,  0.1446, -0.1914],
           [ 0.0579, -0.0305, -0.0455],
           [ 0.0444,  0.0781,  0.0775]],

          [[-0.0222, -0.0779, -0.0636],
           [ 0.0469, -0.0557, -0.1399],
           [ 0.0318, -0.0813,  0.1347]]]],



        [[[[-0.0502,  0.0246, -0.0428],
           [-0.0828, -0.0079,  0.0737],
           [-0.0294, -0.0037, -0.1708]],

          [[ 0.1563, -0.1527, -0.0792],
           [-0.0177, -0.0623,  0.0886],
           [ 0.1491, -0.0406,  0.1631]],

          [[ 0.0269, -0.0537,  0.0033],
           [-0.0455, -0.1445, -0.0463],
           [ 0.0604,  0.0072, -0.0146]]]],



        [[[[-0.0054, -0.0723, -0.0212],
           [ 0.1068,  0.0607, -0.1054],
           [ 0.0669, -0.1795,  0.0028]],

          [[-0.1724, -0.0216, -0.0660],
           [-0.1733, -0.1642,  0.1605],
           [ 0.1911,  0.0534, -0.0471]],
```

```
          [[ 0.0810, -0.1921,  0.0469],
           [-0.1514, -0.0678,  0.1762],
           [-0.0692, -0.1507, -0.0627]]],



        ...,



        [[[[-0.0140,  0.0268, -0.1148],
           [ 0.0892, -0.1212, -0.0074],
           [-0.1624, -0.0195,  0.0699]],

          [[-0.0264,  0.1300, -0.1333],
           [ 0.0680, -0.1830, -0.1071],
           [ 0.1740,  0.1270,  0.0659]],

          [[-0.0789,  0.0085, -0.1047],
           [ 0.1221,  0.1676,  0.1558],
           [-0.0292,  0.1047, -0.0966]]]],



        [[[[ 0.1697, -0.1921,  0.0939],
           [-0.0912,  0.1448,  0.0151],
           [-0.0175,  0.1498, -0.1834]],

          [[ 0.1830,  0.0133,  0.0265],
           [-0.0788,  0.0429, -0.1748],
           [ 0.0659, -0.0358, -0.0319]],

          [[-0.1480,  0.1584,  0.1042],
           [ 0.1247, -0.0867, -0.1806],
           [ 0.1853,  0.0317, -0.0182]]]],



        [[[[-0.0079, -0.0496, -0.1415],
           [ 0.1838, -0.0929,  0.0695],
           [-0.1843,  0.1402, -0.0391]],

          [[-0.0774,  0.0716,  0.1284],
           [-0.0522,  0.0897, -0.0150],
           [-0.1839,  0.0350, -0.1269]],

          [[-0.1503, -0.1157,  0.0273],
           [ 0.1310,  0.0675,  0.0472],
           [ 0.1407,  0.0690, -0.0386]]]], device='cuda:0')
decoder.deconv3.bias tensor([0.0460], device='cuda:0')
```

```
from torch.cuda.amp import autocast, GradScaler
from torch.utils.tensorboard import SummaryWriter
from tqdm import tqdm

# Define the loss function for AE
def ae_loss(x, recon_x):
    recon_loss = nn.functional.mse_loss(recon_x, x, reduction='sum')
    return recon_loss

# Train the AE model
def train(model, train_dataloader, val_dataloader, optimizer, epochs,
device):
    model.train()
    scaler = GradScaler()  # Initialize GradScaler
    best_loss = float('inf')
    for epoch in range(epochs):
        total_loss = 0
        pbar = tqdm(train_dataloader, desc=f"Epoch
{epoch+1}/{epochs}")
        for batch in pbar:
            batch = batch[0].to(device)
            optimizer.zero_grad()
            # Use autocast for mixed precision training
            with autocast():
                recon_x = model(batch)
                loss = ae_loss(batch, recon_x)
            # Scale the loss and call backward() to create scaled
gradients
            scaler.scale(loss).backward()
            # Unscales the gradients of optimizer's assigned params
in-place and call step() to update params
            scaler.step(optimizer)
            # Updates the scale for next iteration
            scaler.update()
            total_loss += loss.item()
            pbar.set_postfix({'loss': total_loss / (pbar.n + 1)})
        avg_loss = total_loss / len(train_dataloader)
        writer.add_scalar('Loss/train', avg_loss, epoch)  # Log the
average loss for this epoch

        # Validate and save the best model every 10 epochs
        if epoch % 10 == 0:
            model.eval()
            val_loss = 0
            with torch.no_grad():
                for batch in val_dataloader:
                    batch = batch[0].to(device)
                    recon_x = model(batch)
                    loss = ae_loss(batch, recon_x)
                    val_loss += loss.item()
```

```
            avg_val_loss = val_loss / len(val_dataloader)
            writer.add_scalar('Loss/val', avg_val_loss, epoch)  # Log
the average validation loss for this epoch
            if avg_val_loss < best_loss:
                best_loss = avg_val_loss
                torch.save(model.state_dict(),
"movingmnist_ae_best.pth")
            model.train()

# Set up device
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
# Define the model
input_shape = x_train.shape[1:]
latent_dim = 20
model = AE(input_shape, latent_dim).to(device)

# Define the optimizer
optimizer = optim.Adam(model.parameters(), lr=1e-6, weight_decay=1e-6)

# Train the model
epochs = 100
train(model, train_loader, val_loader, optimizer, epochs, device)
writer.close()
```

```
Epoch 1/100: 100%|██████████| 71/71 [00:28<00:00,  2.47it/s,
loss=6.68e+6]
Epoch 2/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=6.34e+6]
Epoch 3/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=6.1e+6]
Epoch 4/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=5.91e+6]
Epoch 5/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5.77e+6]
Epoch 6/100: 100%|██████████| 71/71 [00:27<00:00,  2.63it/s,
loss=5.67e+6]
Epoch 7/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.6e+6]
Epoch 8/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.54e+6]
Epoch 9/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.49e+6]
Epoch 10/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=5.46e+6]
Epoch 11/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5.42e+6]
Epoch 12/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=5.4e+6]
Epoch 13/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.38e+6]
```

```
Epoch 14/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=5.35e+6]
Epoch 15/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=5.34e+6]
Epoch 16/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=5.32e+6]
Epoch 17/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.3e+6]
Epoch 18/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.28e+6]
Epoch 19/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.27e+6]
Epoch 20/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=5.26e+6]
Epoch 21/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.24e+6]
Epoch 22/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.23e+6]
Epoch 23/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.22e+6]
Epoch 24/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=5.21e+6]
Epoch 25/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.2e+6]
Epoch 26/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.18e+6]
Epoch 27/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.18e+6]
Epoch 28/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.16e+6]
Epoch 29/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=5.15e+6]
Epoch 30/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=5.14e+6]
Epoch 31/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=5.13e+6]
Epoch 32/100: 100%|██████████| 71/71 [00:27<00:00,  2.54it/s,
loss=5.12e+6]
Epoch 33/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=5.1e+6]
Epoch 34/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5.09e+6]
Epoch 35/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5.08e+6]
Epoch 36/100: 100%|██████████| 71/71 [00:27<00:00,  2.55it/s,
loss=5.07e+6]
Epoch 37/100: 100%|██████████| 71/71 [00:28<00:00,  2.52it/s,
loss=5.05e+6]
Epoch 38/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
```

```
loss=5.03e+6]
Epoch 39/100: 100%|██████████| 71/71 [00:27<00:00,  2.55it/s,
loss=5.03e+6]
Epoch 40/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5.02e+6]
Epoch 41/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=5e+6]
Epoch 42/100: 100%|██████████| 71/71 [00:28<00:00,  2.53it/s,
loss=4.98e+6]
Epoch 43/100: 100%|██████████| 71/71 [00:27<00:00,  2.55it/s,
loss=4.96e+6]
Epoch 44/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=4.95e+6]
Epoch 45/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.93e+6]
Epoch 46/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.91e+6]
Epoch 47/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.9e+6]
Epoch 48/100: 100%|██████████| 71/71 [00:31<00:00,  2.26it/s,
loss=4.88e+6]
Epoch 49/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=4.86e+6]
Epoch 50/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=4.84e+6]
Epoch 51/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=4.82e+6]
Epoch 52/100: 100%|██████████| 71/71 [00:27<00:00,  2.54it/s,
loss=4.8e+6]
Epoch 53/100: 100%|██████████| 71/71 [00:28<00:00,  2.52it/s,
loss=4.78e+6]
Epoch 54/100: 100%|██████████| 71/71 [00:28<00:00,  2.46it/s,
loss=4.77e+6]
Epoch 55/100: 100%|██████████| 71/71 [00:29<00:00,  2.41it/s,
loss=4.75e+6]
Epoch 56/100: 100%|██████████| 71/71 [00:28<00:00,  2.51it/s,
loss=4.73e+6]
Epoch 57/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.71e+6]
Epoch 58/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.69e+6]
Epoch 59/100: 100%|██████████| 71/71 [00:30<00:00,  2.36it/s,
loss=4.67e+6]
Epoch 60/100: 100%|██████████| 71/71 [00:28<00:00,  2.52it/s,
loss=4.66e+6]
Epoch 61/100: 100%|██████████| 71/71 [00:27<00:00,  2.55it/s,
loss=4.64e+6]
Epoch 62/100: 100%|██████████| 71/71 [00:26<00:00,  2.63it/s,
loss=4.62e+6]
```

```
Epoch 63/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.61e+6]
Epoch 64/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.59e+6]
Epoch 65/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.58e+6]
Epoch 66/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.57e+6]
Epoch 67/100: 100%|██████████| 71/71 [00:27<00:00,  2.54it/s,
loss=4.55e+6]
Epoch 68/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.54e+6]
Epoch 69/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.53e+6]
Epoch 70/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.52e+6]
Epoch 71/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=4.5e+6]
Epoch 72/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.49e+6]
Epoch 73/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.47e+6]
Epoch 74/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=4.46e+6]
Epoch 75/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.45e+6]
Epoch 76/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.45e+6]
Epoch 77/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.43e+6]
Epoch 78/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.42e+6]
Epoch 79/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.42e+6]
Epoch 80/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.41e+6]
Epoch 81/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.39e+6]
Epoch 82/100: 100%|██████████| 71/71 [00:28<00:00,  2.52it/s,
loss=4.39e+6]
Epoch 83/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.38e+6]
Epoch 84/100: 100%|██████████| 71/71 [00:28<00:00,  2.52it/s,
loss=4.37e+6]
Epoch 85/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=4.36e+6]
Epoch 86/100: 100%|██████████| 71/71 [00:27<00:00,  2.56it/s,
loss=4.36e+6]
Epoch 87/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
```

```
loss=4.35e+6]
Epoch 88/100: 100%|██████████| 71/71 [00:27<00:00,  2.61it/s,
loss=4.34e+6]
Epoch 89/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.33e+6]
Epoch 90/100: 100%|██████████| 71/71 [00:27<00:00,  2.57it/s,
loss=4.33e+6]
Epoch 91/100: 100%|██████████| 71/71 [00:30<00:00,  2.36it/s,
loss=4.32e+6]
Epoch 92/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.32e+6]
Epoch 93/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.31e+6]
Epoch 94/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.3e+6]
Epoch 95/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.3e+6]
Epoch 96/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.29e+6]
Epoch 97/100: 100%|██████████| 71/71 [00:27<00:00,  2.59it/s,
loss=4.29e+6]
Epoch 98/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.28e+6]
Epoch 99/100: 100%|██████████| 71/71 [00:27<00:00,  2.60it/s,
loss=4.28e+6]
Epoch 100/100: 100%|██████████| 71/71 [00:27<00:00,  2.58it/s,
loss=4.27e+6]
```

```python
# Visualize some example reconstructions
import matplotlib.pyplot as plt

model.eval()
with torch.no_grad():
    for examples in val_loader:
        examples = examples[0].to(device)
        *_, recon_examples = model(examples)
        break

examples = examples.cpu().numpy()
recon_examples = recon_examples.cpu().numpy()

fig, axes = plt.subplots(2, 10, figsize=(20, 4))
for i in range(10):
    axes[0, i].imshow(examples[i, 0], cmap='gray')
    axes[0, i].axis('off')
    axes[1, i].imshow(recon_examples[i, 0], cmap='gray')
    axes[1, i].axis('off')
plt.show()
```