

# Project 4

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Learning deep generative model by alternative back-propagation

```
[ ]: import os
import torch
import numpy as np
import torch.nn as nn
from PIL import Image
from torch.autograd import Variable
from matplotlib import pyplot as plt
from torchvision import transforms as T
from torchvision.utils import make_grid
%matplotlib inline
torch.manual_seed(1203)
torch.cuda.manual_seed(1203)
```

Configs

```
[ ]: class Config(object):
    def __init__(self):
        self.device = 'cuda' if torch.cuda.is_available() else 'cpu'
        self.langevin_steps = 20
        self.langevin_step_size = 0.1
        self.sigma = 1
        self.epochs = 1000
        self.lr = 1e-3
        self.interpolation_d = 5
        self.warm_start = None

args = Config()
```

Dataset

```
[ ]: def load_data(data_dir='images'):
    imgs = []
    transform = T.Compose([T.Resize([128, 128]), T.ToTensor(), T.Normalize((0.
↪5, 0.5, 0.5), (0.5, 0.5, 0.5))])
```

```

for fname in os.listdir(data_dir):
    img = Image.open(os.path.join(data_dir, fname)).convert('RGB')
    img = transform(img)
    imgs.append(img)

imgs = torch.stack(imgs)
return imgs

```

Model

```

[ ]: def set_cuda(deterministic=True):
    if torch.cuda.is_available():
        if deterministic:
            torch.backends.cudnn.deterministic = True
            torch.backends.cudnn.benchmark = False
        else:
            torch.backends.cudnn.deterministic = False
            torch.backends.cudnn.benchmark = True

class GenNet(nn.Module):
    def __init__(self):
        """
        Decode a 2-dim latent variable z to form an output image at 128x128.
        The latent z is first used for a combination of two base feature map at
        ↪ 4x4, which further goes through transposed conv to 128x128.
        (2) -> (512, 4, 4) -> (512, 8, 8) -> (256, 16, 16) -> (128, 32, 32) ->
        ↪ (64, 64, 64) -> (3, 128, 128)
        """
        super().__init__()
        self.latent_base = nn.Parameter(torch.zeros(2, 512*4*4))
        self.block1 = nn.Sequential(
            nn.ConvTranspose2d(in_channels=512, out_channels=512,
            ↪ kernel_size=4, stride=2, padding=1),
            nn.BatchNorm2d(num_features=512),
            nn.ReLU(inplace=True)
        )
        self.block2 = nn.Sequential(
            nn.ConvTranspose2d(in_channels=512, out_channels=256,
            ↪ kernel_size=4, stride=2, padding=1),
            nn.BatchNorm2d(num_features=256),
            nn.ReLU(inplace=True)
        )
        self.block3 = nn.Sequential(
            nn.ConvTranspose2d(in_channels=256, out_channels=128,
            ↪ kernel_size=4, stride=2, padding=1),

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        nn.BatchNorm2d(num_features=128),
        nn.ReLU(inplace=True)
    )
    self.block4 = nn.Sequential(
        nn.ConvTranspose2d(in_channels=128, out_channels=64, kernel_size=4,
↪stride=2, padding=1),
        nn.BatchNorm2d(num_features=64),
        nn.ReLU(inplace=True)
    )
    self.block5 = nn.Sequential(
        nn.ConvTranspose2d(in_channels=64, out_channels=3, kernel_size=4,
↪stride=2, padding=1),
        nn.BatchNorm2d(num_features=3),
        nn.Tanh()
    )

    def forward(self, z):
        z = z.to(self.latent_base.device)
        x = z.view(-1, 2) @ self.latent_base
        # [8192]
        x = x.view(-1, 512, 4, 4)
        # [512, 4, 4]
        x = self.block1(x)
        # [512, 8, 8]
        x = self.block2(x)
        # [256, 16, 16]
        x = self.block3(x)
        # [128, 32, 32]
        x = self.block4(x)
        # [64, 64, 64]
        x = self.block5(x)
        # [3, 128, 128]
        return x

def weights_init_xavier(m):
    classname = m.__class__.__name__
    if 'Conv' in classname:
        nn.init.xavier_normal_(m.weight)
    elif 'BatchNorm' in classname:
        m.weight.data.normal_(1, 0.02)
        m.bias.data.fill_(0)

def compute_logit(I, z, g, sigma):
    # return the log likelihood on joint distribution, log p(I,z/theta)
    I = I.to(g.device)

```

```

return - ((I-g)**2).sum() / (2 * sigma**2) - (z**2).sum() / 2

class Model(nn.Module):
    def __init__(self, args):
        super().__init__()
        self.langevin_steps = args.langevin_steps
        self.langevin_step_size = args.langevin_step_size
        self.sigma = args.sigma
        self.lr = args.lr

        self.Generator = GenNet()
        self.Generator.apply(weights_init_xavier)
        self.Generator.to(args.device)

    def sample_langevin(self, z, I, warm_start=True):
        if not warm_start:
            z = torch.randn(2)

        for i in range(self.langevin_steps):
            z = Variable(z.data, requires_grad=True)
            self.Generator.zero_grad()
            g = self.Generator(z)
            logit = compute_logit(I, z, g, self.sigma)
            logit.backward()

            norm = torch.linalg.norm(z.grad)
            if norm > 1:
                grad = z.grad / norm
            else:
                grad = z.grad
            noise = torch.randn_like(z, device=z.device)
            z.data += self.langevin_step_size**2 * grad / 2 + self.
↪langevin_step_size * noise

        return z.detach()

    def update(self, latents, imgs, warm_start=True):
        """
        latents: [N, 2]
        imgs: [N, 3, 128, 128]
        """
        named_grads = {}
        z_new = []
        loss = []
        print('Collecting gradients')
        for z, I in zip(latents, imgs):

```

```

z = self.sample_langevin(z, I, warm_start)

self.Generator.zero_grad()
g = self.Generator(z)
logit = compute_logit(I, z, g, self.sigma)
logit.backward()

# collect gradients
for n, p in self.Generator.named_parameters():
    if n not in named_grads.keys():
        named_grads.update({n: []})
        named_grads[n].append(p.grad.data)

z_new.append(z.view(-1, 2))
# record loss (negative log likelihood)
loss.append(-logit.detach().item())

# update parameters
print('Updating parameters')
for n, p in self.Generator.named_parameters():
    grad = torch.stack(named_grads[n], dim=0).mean(0)
    norm = torch.linalg.norm(grad)
    if norm > 1:
        grad /= norm
    p.data += self.lr * grad

return torch.cat(z_new, dim=0).detach(), np.mean(loss)

```

Visualization tools

```

[ ]: @torch.no_grad()
def sample_img(model, z):
    sample = model.Generator(z)
    sample = sample.squeeze().detach().cpu().numpy()
    # [-1, 1] to [0, 1]
    sample = (sample + 1) / 2
    # [C, H, W] to [H, W, C]
    sample = sample.transpose(1, 2, 0)
    return sample

def visualize_img_tensor(img_tensor, title_str):
    if img_tensor.ndim == 4:
        img_tensor = img_tensor[0]
    img_array = img_tensor.detach().cpu().numpy().transpose(1, 2, 0)
    if img_array.mean() > 1:
        img_array = (img_array / 255).clip(0, 1)

```

```

else:
    img_array = img_array.clip(0, 1)
plt.figure()
plt.imshow(img_array)
plt.title(title_str)
plt.axis('off')

@torch.no_grad()
def show_interpolation(model, d):
    # make 10x10 grids from interpolation within [-d, d] in latent space
    inter_range = torch.linspace(-d, d, 10)
    xs, ys = torch.meshgrid([inter_range, inter_range], indexing='xy')
    latents = torch.stack([xs, ys], dim=-1)
    latents = latents.reshape(-1, 2) # [100, 2]
    samples = model.Generator(latents)
    samples = (samples + 1) / 2
    vis_grid = make_grid(samples, nrow=10)
    visualize_img_tensor(vis_grid, 'Interpolation in latent space')

def visualize_loss(losses):
    plt.figure()
    plt.plot(losses)
    plt.title('Loss over iterations')
    plt.xlabel('Iteration')
    plt.ylabel('Loss')

```

## Experiment

```

[ ]: def run(args):
    imgs = load_data()
    print(f'Loaded {len(imgs)} images')
    latents = torch.randn(len(imgs), 2)
    model = Model(args)
    losses = []
    for i in range(args.epochs):
        print(f'Epoch {i} update:')
        latents, loss = model.update(latents, imgs, args.warm_start)
        print(f'Epoch {i} loss: {loss:.4f}')
        losses.append(loss)

    visualize_loss(losses)

    plt.figure()
    plt.title('Random sample')
    plt.imshow(sample_img(model, torch.randn(2)))

```

```
plt.axis('off')

show_interpolation(model, args.interpolation_d)
```

Warm start

```
[ ]: setattr(args, 'warm_start', True)
run(args)
```

```
Loaded 11 images
Epoch 0 update:
Collecting gradients
Updating parameters
Epoch 0 loss: 14694.1272
Epoch 1 update:
Collecting gradients
Updating parameters
Epoch 1 loss: 14285.5442
Epoch 2 update:
Collecting gradients
Updating parameters
Epoch 2 loss: 13891.8097
Epoch 3 update:
Collecting gradients
Updating parameters
Epoch 3 loss: 13885.8010
Epoch 4 update:
Collecting gradients
Updating parameters
Epoch 4 loss: 13649.8286
Epoch 5 update:
Collecting gradients
Updating parameters
Epoch 5 loss: 13415.3176
Epoch 6 update:
Collecting gradients
Updating parameters
Epoch 6 loss: 13307.5075
Epoch 7 update:
Collecting gradients
Updating parameters
Epoch 7 loss: 13005.5139
Epoch 8 update:
Collecting gradients
Updating parameters
Epoch 8 loss: 12830.6221
Epoch 9 update:
Collecting gradients
```

Updating parameters  
Epoch 9 loss: 12653.6732  
Epoch 10 update:  
Collecting gradients  
Updating parameters  
Epoch 10 loss: 12380.0906  
Epoch 11 update:  
Collecting gradients  
Updating parameters  
Epoch 11 loss: 12219.1461  
Epoch 12 update:  
Collecting gradients  
Updating parameters  
Epoch 12 loss: 12093.6548  
Epoch 13 update:  
Collecting gradients  
Updating parameters  
Epoch 13 loss: 12243.1768  
Epoch 14 update:  
Collecting gradients  
Updating parameters  
Epoch 14 loss: 12097.6585  
Epoch 15 update:  
Collecting gradients  
Updating parameters  
Epoch 15 loss: 12174.7947  
Epoch 16 update:  
Collecting gradients  
Updating parameters  
Epoch 16 loss: 11965.5045  
Epoch 17 update:  
Collecting gradients  
Updating parameters  
Epoch 17 loss: 11930.8185  
Epoch 18 update:  
Collecting gradients  
Updating parameters  
Epoch 18 loss: 11793.9137  
Epoch 19 update:  
Collecting gradients  
Updating parameters  
Epoch 19 loss: 11776.6341  
Epoch 20 update:  
Collecting gradients  
Updating parameters  
Epoch 20 loss: 11739.7716  
Epoch 21 update:  
Collecting gradients



Updating parameters  
Epoch 21 loss: 11570.2972  
Epoch 22 update:  
Collecting gradients  
Updating parameters  
Epoch 22 loss: 11494.2496  
Epoch 23 update:  
Collecting gradients  
Updating parameters  
Epoch 23 loss: 11474.4596  
Epoch 24 update:  
Collecting gradients  
Updating parameters  
Epoch 24 loss: 11268.3200  
Epoch 25 update:  
Collecting gradients  
Updating parameters  
Epoch 25 loss: 10978.4258  
Epoch 26 update:  
Collecting gradients  
Updating parameters  
Epoch 26 loss: 11039.0083  
Epoch 27 update:  
Collecting gradients  
Updating parameters  
Epoch 27 loss: 11122.2630  
Epoch 28 update:  
Collecting gradients  
Updating parameters  
Epoch 28 loss: 11305.7292  
Epoch 29 update:  
Collecting gradients  
Updating parameters  
Epoch 29 loss: 11076.0966  
Epoch 30 update:  
Collecting gradients  
Updating parameters  
Epoch 30 loss: 10989.2868  
Epoch 31 update:  
Collecting gradients  
Updating parameters  
Epoch 31 loss: 10750.7468  
Epoch 32 update:  
Collecting gradients  
Updating parameters  
Epoch 32 loss: 11186.2703  
Epoch 33 update:  
Collecting gradients

Updating parameters  
Epoch 33 loss: 11379.8299  
Epoch 34 update:  
Collecting gradients  
Updating parameters  
Epoch 34 loss: 10939.9539  
Epoch 35 update:  
Collecting gradients  
Updating parameters  
Epoch 35 loss: 10914.6358  
Epoch 36 update:  
Collecting gradients  
Updating parameters  
Epoch 36 loss: 10316.2453  
Epoch 37 update:  
Collecting gradients  
Updating parameters  
Epoch 37 loss: 10657.7259  
Epoch 38 update:  
Collecting gradients  
Updating parameters  
Epoch 38 loss: 10539.8940  
Epoch 39 update:  
Collecting gradients  
Updating parameters  
Epoch 39 loss: 10374.5597  
Epoch 40 update:  
Collecting gradients  
Updating parameters  
Epoch 40 loss: 10493.1552  
Epoch 41 update:  
Collecting gradients  
Updating parameters  
Epoch 41 loss: 9998.7530  
Epoch 42 update:  
Collecting gradients  
Updating parameters  
Epoch 42 loss: 9935.1996  
Epoch 43 update:  
Collecting gradients  
Updating parameters  
Epoch 43 loss: 10084.4145  
Epoch 44 update:  
Collecting gradients  
Updating parameters  
Epoch 44 loss: 10144.6085  
Epoch 45 update:  
Collecting gradients

Updating parameters  
Epoch 45 loss: 10235.9528  
Epoch 46 update:  
Collecting gradients  
Updating parameters  
Epoch 46 loss: 10053.6412  
Epoch 47 update:  
Collecting gradients  
Updating parameters  
Epoch 47 loss: 9983.6396  
Epoch 48 update:  
Collecting gradients  
Updating parameters  
Epoch 48 loss: 10221.1965  
Epoch 49 update:  
Collecting gradients  
Updating parameters  
Epoch 49 loss: 10334.7198  
Epoch 50 update:  
Collecting gradients  
Updating parameters  
Epoch 50 loss: 10335.3165  
Epoch 51 update:  
Collecting gradients  
Updating parameters  
Epoch 51 loss: 10025.3362  
Epoch 52 update:  
Collecting gradients  
Updating parameters  
Epoch 52 loss: 9844.7103  
Epoch 53 update:  
Collecting gradients  
Updating parameters  
Epoch 53 loss: 9775.6924  
Epoch 54 update:  
Collecting gradients  
Updating parameters  
Epoch 54 loss: 9574.5522  
Epoch 55 update:  
Collecting gradients  
Updating parameters  
Epoch 55 loss: 9699.9440  
Epoch 56 update:  
Collecting gradients  
Updating parameters  
Epoch 56 loss: 9671.0351  
Epoch 57 update:  
Collecting gradients

Updating parameters  
Epoch 57 loss: 9582.5640  
Epoch 58 update:  
Collecting gradients  
Updating parameters  
Epoch 58 loss: 9670.2343  
Epoch 59 update:  
Collecting gradients  
Updating parameters  
Epoch 59 loss: 9452.3288  
Epoch 60 update:  
Collecting gradients  
Updating parameters  
Epoch 60 loss: 9295.3927  
Epoch 61 update:  
Collecting gradients  
Updating parameters  
Epoch 61 loss: 9417.9402  
Epoch 62 update:  
Collecting gradients  
Updating parameters  
Epoch 62 loss: 9390.0927  
Epoch 63 update:  
Collecting gradients  
Updating parameters  
Epoch 63 loss: 9375.1071  
Epoch 64 update:  
Collecting gradients  
Updating parameters  
Epoch 64 loss: 9289.7290  
Epoch 65 update:  
Collecting gradients  
Updating parameters  
Epoch 65 loss: 9148.5274  
Epoch 66 update:  
Collecting gradients  
Updating parameters  
Epoch 66 loss: 9140.7297  
Epoch 67 update:  
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Updating parameters  
Epoch 67 loss: 8990.4147  
Epoch 68 update:  
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Updating parameters  
Epoch 68 loss: 9127.2089  
Epoch 69 update:  
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Updating parameters  
Epoch 69 loss: 9055.0820  
Epoch 70 update:  
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Updating parameters  
Epoch 70 loss: 9114.1965  
Epoch 71 update:  
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Updating parameters  
Epoch 71 loss: 9033.3014  
Epoch 72 update:  
Collecting gradients  
Updating parameters  
Epoch 72 loss: 8876.6396  
Epoch 73 update:  
Collecting gradients  
Updating parameters  
Epoch 73 loss: 8878.7731  
Epoch 74 update:  
Collecting gradients  
Updating parameters  
Epoch 74 loss: 8866.1636  
Epoch 75 update:  
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Updating parameters  
Epoch 75 loss: 8827.4671  
Epoch 76 update:  
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Epoch 76 loss: 8821.5862  
Epoch 77 update:  
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Updating parameters  
Epoch 77 loss: 8740.4895  
Epoch 78 update:  
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Updating parameters  
Epoch 78 loss: 8619.8930  
Epoch 79 update:  
Collecting gradients  
Updating parameters  
Epoch 79 loss: 8588.9786  
Epoch 80 update:  
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Epoch 80 loss: 8506.9780  
Epoch 81 update:  
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Epoch 81 loss: 8555.2777  
Epoch 82 update:  
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Epoch 82 loss: 8609.2190  
Epoch 83 update:  
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Epoch 83 loss: 8490.9147  
Epoch 84 update:  
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Epoch 84 loss: 8398.0952  
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Epoch 85 loss: 8357.2756  
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Epoch 86 loss: 8293.4948  
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Epoch 87 loss: 8307.0064  
Epoch 88 update:  
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Epoch 89 update:  
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Epoch 89 loss: 8219.1404  
Epoch 90 update:  
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Epoch 90 loss: 8169.3534  
Epoch 91 update:  
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Epoch 91 loss: 8154.0275  
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Epoch 93 loss: 8107.5814  
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Epoch 94 loss: 7989.6410  
Epoch 95 update:  
Collecting gradients  
Updating parameters  
Epoch 95 loss: 7968.4160  
Epoch 96 update:  
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Epoch 96 loss: 8026.9282  
Epoch 97 update:  
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Epoch 97 loss: 7998.4769  
Epoch 98 update:  
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Epoch 98 loss: 7996.9259  
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Epoch 99 loss: 7985.7714  
Epoch 100 update:  
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Epoch 100 loss: 8022.8612  
Epoch 101 update:  
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Epoch 101 loss: 7952.9884  
Epoch 102 update:  
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Epoch 102 loss: 7951.9205  
Epoch 103 update:  
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Epoch 103 loss: 7958.3467  
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Epoch 104 loss: 7982.2465  
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Epoch 105 loss: 8044.1271  
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Epoch 107 loss: 7880.1715  
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Epoch 108 loss: 7854.4644  
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Epoch 109 loss: 7877.6369  
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Epoch 110 loss: 7854.2356  
Epoch 111 update:  
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Epoch 111 loss: 7968.9858  
Epoch 112 update:  
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Epoch 113 update:  
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Epoch 113 loss: 7985.0704  
Epoch 114 update:  
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Epoch 114 loss: 7900.2453  
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Epoch 115 loss: 7888.5189  
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Epoch 116 loss: 7835.2696  
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Epoch 117 loss: 7758.2364  
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Epoch 119 loss: 7756.2820  
Epoch 120 update:  
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Epoch 120 loss: 7774.5579  
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Epoch 121 loss: 7804.1094  
Epoch 122 update:  
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Epoch 122 loss: 7923.3046  
Epoch 123 update:  
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Epoch 126 loss: 7729.6681  
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Epoch 127 loss: 7802.6557  
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Epoch 128 loss: 7787.9197  
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Epoch 129 loss: 7789.5791  
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Epoch 130 loss: 7734.5899  
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Collecting gradients  
Updating parameters  
Epoch 131 loss: 7739.1319  
Epoch 132 update:  
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Epoch 132 loss: 7812.0728  
Epoch 133 update:  
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Epoch 133 loss: 7745.1734  
Epoch 134 update:  
Collecting gradients  
Updating parameters  
Epoch 134 loss: 7707.3659  
Epoch 135 update:  
Collecting gradients  
Updating parameters  
Epoch 135 loss: 7785.8108  
Epoch 136 update:  
Collecting gradients  
Updating parameters  
Epoch 136 loss: 7671.0069  
Epoch 137 update:  
Collecting gradients  
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Epoch 137 loss: 7658.1742  
Epoch 138 update:  
Collecting gradients  
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Epoch 138 loss: 7650.9751  
Epoch 139 update:  
Collecting gradients  
Updating parameters  
Epoch 139 loss: 7679.3327  
Epoch 140 update:  
Collecting gradients  
Updating parameters  
Epoch 140 loss: 7707.1118  
Epoch 141 update:  
Collecting gradients

Updating parameters  
Epoch 141 loss: 7661.0127  
Epoch 142 update:  
Collecting gradients  
Updating parameters  
Epoch 142 loss: 7647.1854  
Epoch 143 update:  
Collecting gradients  
Updating parameters  
Epoch 143 loss: 7701.1619  
Epoch 144 update:  
Collecting gradients  
Updating parameters  
Epoch 144 loss: 7987.9621  
Epoch 145 update:  
Collecting gradients  
Updating parameters  
Epoch 145 loss: 7566.6777  
Epoch 146 update:  
Collecting gradients  
Updating parameters  
Epoch 146 loss: 7595.8037  
Epoch 147 update:  
Collecting gradients  
Updating parameters  
Epoch 147 loss: 7586.1391  
Epoch 148 update:  
Collecting gradients  
Updating parameters  
Epoch 148 loss: 7564.7910  
Epoch 149 update:  
Collecting gradients  
Updating parameters  
Epoch 149 loss: 7552.5184  
Epoch 150 update:  
Collecting gradients  
Updating parameters  
Epoch 150 loss: 7595.1968  
Epoch 151 update:  
Collecting gradients  
Updating parameters  
Epoch 151 loss: 7514.2476  
Epoch 152 update:  
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Updating parameters  
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Updating parameters  
Epoch 882 loss: 6290.2662  
Epoch 883 update:  
Collecting gradients  
Updating parameters  
Epoch 883 loss: 6310.9575  
Epoch 884 update:  
Collecting gradients  
Updating parameters  
Epoch 884 loss: 6344.4164  
Epoch 885 update:  
Collecting gradients



Updating parameters  
Epoch 885 loss: 6219.7675  
Epoch 886 update:  
Collecting gradients  
Updating parameters  
Epoch 886 loss: 6285.6398  
Epoch 887 update:  
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Updating parameters  
Epoch 887 loss: 6308.0139  
Epoch 888 update:  
Collecting gradients  
Updating parameters  
Epoch 888 loss: 6156.9238  
Epoch 889 update:  
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Updating parameters  
Epoch 889 loss: 6155.1616  
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Collecting gradients  
Updating parameters  
Epoch 890 loss: 6236.5600  
Epoch 891 update:  
Collecting gradients  
Updating parameters  
Epoch 891 loss: 6261.4649  
Epoch 892 update:  
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Updating parameters  
Epoch 892 loss: 6279.7810  
Epoch 893 update:  
Collecting gradients  
Updating parameters  
Epoch 893 loss: 6501.8166  
Epoch 894 update:  
Collecting gradients  
Updating parameters  
Epoch 894 loss: 6516.0369  
Epoch 895 update:  
Collecting gradients  
Updating parameters  
Epoch 895 loss: 6545.2645  
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Updating parameters  
Epoch 896 loss: 6297.2497  
Epoch 897 update:  
Collecting gradients

Updating parameters  
Epoch 897 loss: 6340.8994  
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Updating parameters  
Epoch 898 loss: 6344.1272  
Epoch 899 update:  
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Updating parameters  
Epoch 899 loss: 6416.9909  
Epoch 900 update:  
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Updating parameters  
Epoch 900 loss: 6247.6305  
Epoch 901 update:  
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Updating parameters  
Epoch 901 loss: 6071.5363  
Epoch 902 update:  
Collecting gradients  
Updating parameters  
Epoch 902 loss: 6063.1078  
Epoch 903 update:  
Collecting gradients  
Updating parameters  
Epoch 903 loss: 6116.7399  
Epoch 904 update:  
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Updating parameters  
Epoch 904 loss: 6132.7077  
Epoch 905 update:  
Collecting gradients  
Updating parameters  
Epoch 905 loss: 6101.4228  
Epoch 906 update:  
Collecting gradients  
Updating parameters  
Epoch 906 loss: 6146.2786  
Epoch 907 update:  
Collecting gradients  
Updating parameters  
Epoch 907 loss: 6098.7649  
Epoch 908 update:  
Collecting gradients  
Updating parameters  
Epoch 908 loss: 5963.1929  
Epoch 909 update:  
Collecting gradients

Updating parameters  
Epoch 909 loss: 5979.8827  
Epoch 910 update:  
Collecting gradients  
Updating parameters  
Epoch 910 loss: 6014.6979  
Epoch 911 update:  
Collecting gradients  
Updating parameters  
Epoch 911 loss: 6027.3113  
Epoch 912 update:  
Collecting gradients  
Updating parameters  
Epoch 912 loss: 6148.4336  
Epoch 913 update:  
Collecting gradients  
Updating parameters  
Epoch 913 loss: 6168.7570  
Epoch 914 update:  
Collecting gradients  
Updating parameters  
Epoch 914 loss: 6007.3725  
Epoch 915 update:  
Collecting gradients  
Updating parameters  
Epoch 915 loss: 6049.7168  
Epoch 916 update:  
Collecting gradients  
Updating parameters  
Epoch 916 loss: 6166.3923  
Epoch 917 update:  
Collecting gradients  
Updating parameters  
Epoch 917 loss: 6202.4344  
Epoch 918 update:  
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Epoch 919 update:  
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Updating parameters  
Epoch 919 loss: 6033.8713  
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Collecting gradients

Updating parameters  
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Updating parameters  
Epoch 922 loss: 5992.6833  
Epoch 923 update:  
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Updating parameters  
Epoch 923 loss: 6062.8234  
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Updating parameters  
Epoch 924 loss: 6114.0322  
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Epoch 925 loss: 6141.9373  
Epoch 926 update:  
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Updating parameters  
Epoch 926 loss: 6239.2013  
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Epoch 930 loss: 6126.8303  
Epoch 931 update:  
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Updating parameters  
Epoch 931 loss: 6047.2952  
Epoch 932 update:  
Collecting gradients  
Updating parameters  
Epoch 932 loss: 6158.4193  
Epoch 933 update:  
Collecting gradients

Updating parameters  
Epoch 933 loss: 6148.7325  
Epoch 934 update:  
Collecting gradients  
Updating parameters  
Epoch 934 loss: 6106.5439  
Epoch 935 update:  
Collecting gradients  
Updating parameters  
Epoch 935 loss: 6090.8136  
Epoch 936 update:  
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Updating parameters  
Epoch 936 loss: 6146.9999  
Epoch 937 update:  
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Updating parameters  
Epoch 937 loss: 6161.6759  
Epoch 938 update:  
Collecting gradients  
Updating parameters  
Epoch 938 loss: 6226.2874  
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Epoch 939 loss: 6108.7502  
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Updating parameters  
Epoch 941 loss: 6011.1343  
Epoch 942 update:  
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Updating parameters  
Epoch 942 loss: 6053.0941  
Epoch 943 update:  
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Updating parameters  
Epoch 943 loss: 6056.6568  
Epoch 944 update:  
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Updating parameters  
Epoch 944 loss: 6051.9882  
Epoch 945 update:  
Collecting gradients

Updating parameters  
Epoch 945 loss: 6100.6342  
Epoch 946 update:  
Collecting gradients  
Updating parameters  
Epoch 946 loss: 6081.3928  
Epoch 947 update:  
Collecting gradients  
Updating parameters  
Epoch 947 loss: 6078.1000  
Epoch 948 update:  
Collecting gradients  
Updating parameters  
Epoch 948 loss: 6050.4092  
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Collecting gradients  
Updating parameters  
Epoch 949 loss: 5979.1699  
Epoch 950 update:  
Collecting gradients  
Updating parameters  
Epoch 950 loss: 6064.2765  
Epoch 951 update:  
Collecting gradients  
Updating parameters  
Epoch 951 loss: 6034.7057  
Epoch 952 update:  
Collecting gradients  
Updating parameters  
Epoch 952 loss: 5942.8190  
Epoch 953 update:  
Collecting gradients  
Updating parameters  
Epoch 953 loss: 5951.9855  
Epoch 954 update:  
Collecting gradients  
Updating parameters  
Epoch 954 loss: 5959.7052  
Epoch 955 update:  
Collecting gradients  
Updating parameters  
Epoch 955 loss: 5959.8726  
Epoch 956 update:  
Collecting gradients  
Updating parameters  
Epoch 956 loss: 5998.5806  
Epoch 957 update:  
Collecting gradients

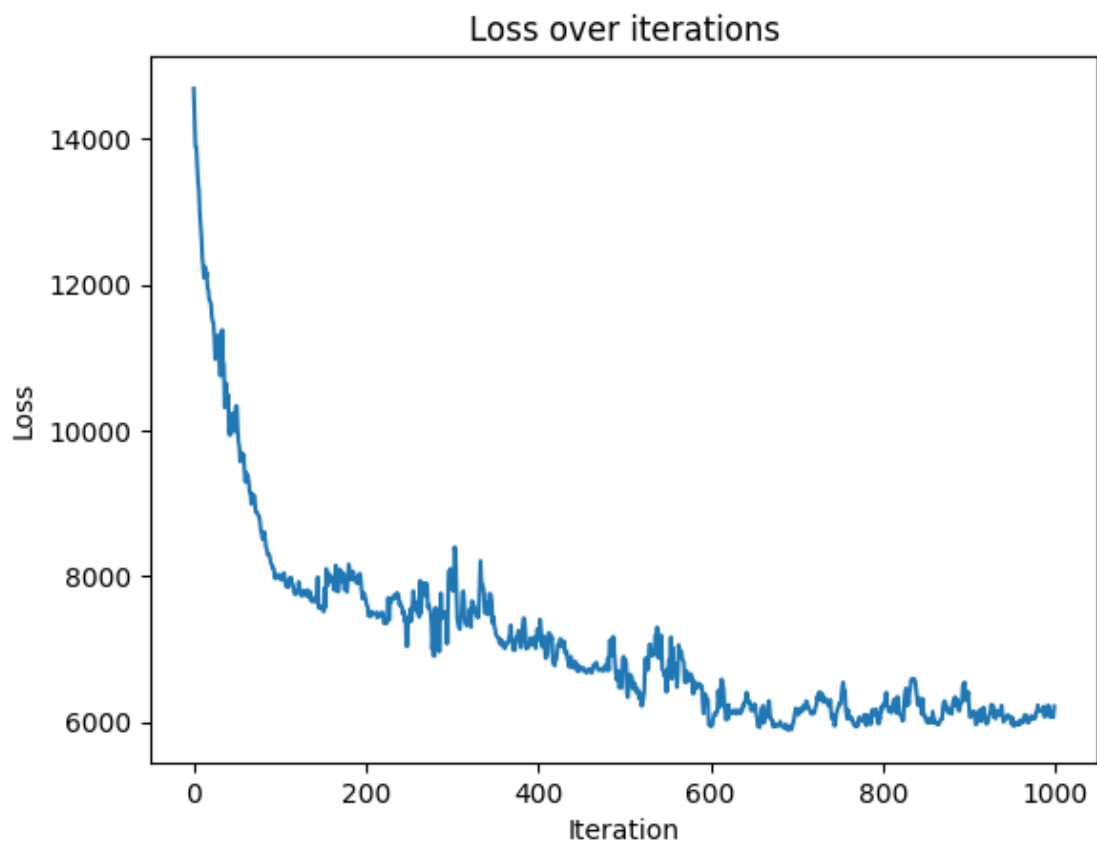
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Epoch 958 update:  
Collecting gradients  
Updating parameters  
Epoch 958 loss: 6001.3695  
Epoch 959 update:  
Collecting gradients  
Updating parameters  
Epoch 959 loss: 5963.3953  
Epoch 960 update:  
Collecting gradients  
Updating parameters  
Epoch 960 loss: 6024.9081  
Epoch 961 update:  
Collecting gradients  
Updating parameters  
Epoch 961 loss: 6019.4562  
Epoch 962 update:  
Collecting gradients  
Updating parameters  
Epoch 962 loss: 6002.6953  
Epoch 963 update:  
Collecting gradients  
Updating parameters  
Epoch 963 loss: 5993.7487  
Epoch 964 update:  
Collecting gradients  
Updating parameters  
Epoch 964 loss: 6077.3574  
Epoch 965 update:  
Collecting gradients  
Updating parameters  
Epoch 965 loss: 6096.0760  
Epoch 966 update:  
Collecting gradients  
Updating parameters  
Epoch 966 loss: 6096.7429  
Epoch 967 update:  
Collecting gradients  
Updating parameters  
Epoch 967 loss: 6070.4189  
Epoch 968 update:  
Collecting gradients  
Updating parameters  
Epoch 968 loss: 5998.9564  
Epoch 969 update:  
Collecting gradients

Updating parameters  
Epoch 969 loss: 5989.1506  
Epoch 970 update:  
Collecting gradients  
Updating parameters  
Epoch 970 loss: 6003.7283  
Epoch 971 update:  
Collecting gradients  
Updating parameters  
Epoch 971 loss: 6035.9888  
Epoch 972 update:  
Collecting gradients  
Updating parameters  
Epoch 972 loss: 6081.7099  
Epoch 973 update:  
Collecting gradients  
Updating parameters  
Epoch 973 loss: 6054.5292  
Epoch 974 update:  
Collecting gradients  
Updating parameters  
Epoch 974 loss: 6078.3442  
Epoch 975 update:  
Collecting gradients  
Updating parameters  
Epoch 975 loss: 6045.6991  
Epoch 976 update:  
Collecting gradients  
Updating parameters  
Epoch 976 loss: 6061.2492  
Epoch 977 update:  
Collecting gradients  
Updating parameters  
Epoch 977 loss: 6054.4878  
Epoch 978 update:  
Collecting gradients  
Updating parameters  
Epoch 978 loss: 6131.5266  
Epoch 979 update:  
Collecting gradients  
Updating parameters  
Epoch 979 loss: 6135.8547  
Epoch 980 update:  
Collecting gradients  
Updating parameters  
Epoch 980 loss: 6230.4581  
Epoch 981 update:  
Collecting gradients



Updating parameters  
Epoch 981 loss: 6172.5316  
Epoch 982 update:  
Collecting gradients  
Updating parameters  
Epoch 982 loss: 6158.4909  
Epoch 983 update:  
Collecting gradients  
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Epoch 983 loss: 6141.2786  
Epoch 984 update:  
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Updating parameters  
Epoch 984 loss: 6155.7216  
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Updating parameters  
Epoch 985 loss: 6147.9136  
Epoch 986 update:  
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Epoch 986 loss: 6170.0809  
Epoch 987 update:  
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Updating parameters  
Epoch 987 loss: 6212.4935  
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Epoch 988 loss: 6069.7692  
Epoch 989 update:  
Collecting gradients  
Updating parameters  
Epoch 989 loss: 6200.9930  
Epoch 990 update:  
Collecting gradients  
Updating parameters  
Epoch 990 loss: 6176.2354  
Epoch 991 update:  
Collecting gradients  
Updating parameters  
Epoch 991 loss: 6165.8562  
Epoch 992 update:  
Collecting gradients  
Updating parameters  
Epoch 992 loss: 6230.9926  
Epoch 993 update:  
Collecting gradients

Updating parameters  
Epoch 993 loss: 6185.6779  
Epoch 994 update:  
Collecting gradients  
Updating parameters  
Epoch 994 loss: 6067.5777  
Epoch 995 update:  
Collecting gradients  
Updating parameters  
Epoch 995 loss: 6130.1984  
Epoch 996 update:  
Collecting gradients  
Updating parameters  
Epoch 996 loss: 6138.3815  
Epoch 997 update:  
Collecting gradients  
Updating parameters  
Epoch 997 loss: 6122.4553  
Epoch 998 update:  
Collecting gradients  
Updating parameters  
Epoch 998 loss: 6066.1602  
Epoch 999 update:  
Collecting gradients  
Updating parameters  
Epoch 999 loss: 6215.0480



Random sample



Interpolation in latent space



Cold start

```
[ ]: setattr(args, 'warm_start', False)
run(args)
```

```
Loaded 11 images
Epoch 0 update:
Collecting gradients
Updating parameters
Epoch 0 loss: 14719.0265
Epoch 1 update:
Collecting gradients
Updating parameters
Epoch 1 loss: 14491.4553
Epoch 2 update:
Collecting gradients
Updating parameters
Epoch 2 loss: 13907.6601
Epoch 3 update:
Collecting gradients
Updating parameters
Epoch 3 loss: 13216.5684
Epoch 4 update:
Collecting gradients
Updating parameters
Epoch 4 loss: 12552.6382
Epoch 5 update:
Collecting gradients
Updating parameters
Epoch 5 loss: 12518.5598
Epoch 6 update:
Collecting gradients
Updating parameters
Epoch 6 loss: 11908.4850
Epoch 7 update:
Collecting gradients
Updating parameters
Epoch 7 loss: 11485.1218
Epoch 8 update:
Collecting gradients
Updating parameters
Epoch 8 loss: 12044.1321
Epoch 9 update:
Collecting gradients
Updating parameters
Epoch 9 loss: 11287.9044
```

Epoch 10 update:  
Collecting gradients  
Updating parameters  
Epoch 10 loss: 11433.3254  
Epoch 11 update:  
Collecting gradients  
Updating parameters  
Epoch 11 loss: 11371.0875  
Epoch 12 update:  
Collecting gradients  
Updating parameters  
Epoch 12 loss: 11219.0518  
Epoch 13 update:  
Collecting gradients  
Updating parameters  
Epoch 13 loss: 10304.8632  
Epoch 14 update:  
Collecting gradients  
Updating parameters  
Epoch 14 loss: 11345.5815  
Epoch 15 update:  
Collecting gradients  
Updating parameters  
Epoch 15 loss: 11016.5489  
Epoch 16 update:  
Collecting gradients  
Updating parameters  
Epoch 16 loss: 10399.4731  
Epoch 17 update:  
Collecting gradients  
Updating parameters  
Epoch 17 loss: 10812.7888  
Epoch 18 update:  
Collecting gradients  
Updating parameters  
Epoch 18 loss: 10100.1676  
Epoch 19 update:  
Collecting gradients  
Updating parameters  
Epoch 19 loss: 10154.6810  
Epoch 20 update:  
Collecting gradients  
Updating parameters  
Epoch 20 loss: 10435.8056  
Epoch 21 update:  
Collecting gradients  
Updating parameters  
Epoch 21 loss: 10351.2986

Epoch 22 update:  
Collecting gradients  
Updating parameters  
Epoch 22 loss: 10049.4269  
Epoch 23 update:  
Collecting gradients  
Updating parameters  
Epoch 23 loss: 10457.1879  
Epoch 24 update:  
Collecting gradients  
Updating parameters  
Epoch 24 loss: 10293.8829  
Epoch 25 update:  
Collecting gradients  
Updating parameters  
Epoch 25 loss: 9467.6499  
Epoch 26 update:  
Collecting gradients  
Updating parameters  
Epoch 26 loss: 9755.7793  
Epoch 27 update:  
Collecting gradients  
Updating parameters  
Epoch 27 loss: 10052.2719  
Epoch 28 update:  
Collecting gradients  
Updating parameters  
Epoch 28 loss: 9449.9662  
Epoch 29 update:  
Collecting gradients  
Updating parameters  
Epoch 29 loss: 9327.7460  
Epoch 30 update:  
Collecting gradients  
Updating parameters  
Epoch 30 loss: 9644.3355  
Epoch 31 update:  
Collecting gradients  
Updating parameters  
Epoch 31 loss: 9650.1919  
Epoch 32 update:  
Collecting gradients  
Updating parameters  
Epoch 32 loss: 9605.2402  
Epoch 33 update:  
Collecting gradients  
Updating parameters  
Epoch 33 loss: 9602.3013

Epoch 34 update:  
Collecting gradients  
Updating parameters  
Epoch 34 loss: 9621.4319  
Epoch 35 update:  
Collecting gradients  
Updating parameters  
Epoch 35 loss: 9413.8536  
Epoch 36 update:  
Collecting gradients  
Updating parameters  
Epoch 36 loss: 9021.7863  
Epoch 37 update:  
Collecting gradients  
Updating parameters  
Epoch 37 loss: 9021.3019  
Epoch 38 update:  
Collecting gradients  
Updating parameters  
Epoch 38 loss: 9015.1264  
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Collecting gradients  
Updating parameters  
Epoch 39 loss: 8878.5981  
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Updating parameters  
Epoch 41 loss: 9007.6364  
Epoch 42 update:  
Collecting gradients  
Updating parameters  
Epoch 42 loss: 8934.5520  
Epoch 43 update:  
Collecting gradients  
Updating parameters  
Epoch 43 loss: 8630.8893  
Epoch 44 update:  
Collecting gradients  
Updating parameters  
Epoch 44 loss: 8742.4274  
Epoch 45 update:  
Collecting gradients  
Updating parameters  
Epoch 45 loss: 8860.9339



Epoch 46 update:  
Collecting gradients  
Updating parameters  
Epoch 46 loss: 8627.7610  
Epoch 47 update:  
Collecting gradients  
Updating parameters  
Epoch 47 loss: 8527.4968  
Epoch 48 update:  
Collecting gradients  
Updating parameters  
Epoch 48 loss: 8482.6941  
Epoch 49 update:  
Collecting gradients  
Updating parameters  
Epoch 49 loss: 8682.8200  
Epoch 50 update:  
Collecting gradients  
Updating parameters  
Epoch 50 loss: 9071.7021  
Epoch 51 update:  
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Updating parameters  
Epoch 51 loss: 8808.5375  
Epoch 52 update:  
Collecting gradients  
Updating parameters  
Epoch 52 loss: 8435.6007  
Epoch 53 update:  
Collecting gradients  
Updating parameters  
Epoch 53 loss: 8327.2373  
Epoch 54 update:  
Collecting gradients  
Updating parameters  
Epoch 54 loss: 8288.0918  
Epoch 55 update:  
Collecting gradients  
Updating parameters  
Epoch 55 loss: 8309.1001  
Epoch 56 update:  
Collecting gradients  
Updating parameters  
Epoch 56 loss: 8349.6557  
Epoch 57 update:  
Collecting gradients  
Updating parameters  
Epoch 57 loss: 8345.4450

Epoch 58 update:  
Collecting gradients  
Updating parameters  
Epoch 58 loss: 8316.8735  
Epoch 59 update:  
Collecting gradients  
Updating parameters  
Epoch 59 loss: 8337.8547  
Epoch 60 update:  
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Updating parameters  
Epoch 60 loss: 8253.7786  
Epoch 61 update:  
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Updating parameters  
Epoch 61 loss: 8349.5759  
Epoch 62 update:  
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Updating parameters  
Epoch 62 loss: 8561.0604  
Epoch 63 update:  
Collecting gradients  
Updating parameters  
Epoch 63 loss: 8285.3055  
Epoch 64 update:  
Collecting gradients  
Updating parameters  
Epoch 64 loss: 8212.0362  
Epoch 65 update:  
Collecting gradients  
Updating parameters  
Epoch 65 loss: 8250.1540  
Epoch 66 update:  
Collecting gradients  
Updating parameters  
Epoch 66 loss: 7960.6414  
Epoch 67 update:  
Collecting gradients  
Updating parameters  
Epoch 67 loss: 8230.5822  
Epoch 68 update:  
Collecting gradients  
Updating parameters  
Epoch 68 loss: 8183.0411  
Epoch 69 update:  
Collecting gradients  
Updating parameters  
Epoch 69 loss: 8212.9599

Epoch 70 update:  
Collecting gradients  
Updating parameters  
Epoch 70 loss: 7897.6582  
Epoch 71 update:  
Collecting gradients  
Updating parameters  
Epoch 71 loss: 8025.8980  
Epoch 72 update:  
Collecting gradients  
Updating parameters  
Epoch 72 loss: 8046.6174  
Epoch 73 update:  
Collecting gradients  
Updating parameters  
Epoch 73 loss: 7948.7488  
Epoch 74 update:  
Collecting gradients  
Updating parameters  
Epoch 74 loss: 7927.9275  
Epoch 75 update:  
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Updating parameters  
Epoch 75 loss: 7942.4684  
Epoch 76 update:  
Collecting gradients  
Updating parameters  
Epoch 76 loss: 7919.9557  
Epoch 77 update:  
Collecting gradients  
Updating parameters  
Epoch 77 loss: 7922.1738  
Epoch 78 update:  
Collecting gradients  
Updating parameters  
Epoch 78 loss: 7879.4865  
Epoch 79 update:  
Collecting gradients  
Updating parameters  
Epoch 79 loss: 8163.8179  
Epoch 80 update:  
Collecting gradients  
Updating parameters  
Epoch 80 loss: 7904.7021  
Epoch 81 update:  
Collecting gradients  
Updating parameters  
Epoch 81 loss: 7981.9806

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Updating parameters  
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Updating parameters  
Epoch 83 loss: 8136.9010  
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Epoch 84 loss: 7784.0253  
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Updating parameters  
Epoch 85 loss: 7846.1666  
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Epoch 86 loss: 7877.6055  
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Epoch 92 loss: 7948.1998  
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Updating parameters  
Epoch 93 loss: 7682.3178

Epoch 94 update:  
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Updating parameters  
Epoch 94 loss: 7777.8762  
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Updating parameters  
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Epoch 105 loss: 7756.4574

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Epoch 106 loss: 7575.0173  
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Updating parameters  
Epoch 107 loss: 7488.1941  
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Updating parameters  
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Epoch 908 loss: 5782.6106  
Epoch 909 update:  
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Updating parameters  
Epoch 909 loss: 6058.9152



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Epoch 919 loss: 5949.7301  
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Epoch 943 loss: 5799.1497  
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Epoch 944 loss: 5842.6648  
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Epoch 945 loss: 5798.8757

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Epoch 950 loss: 5886.3374  
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Epoch 951 loss: 5814.7347  
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Epoch 956 loss: 5803.6524  
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Epoch 957 loss: 5753.3102

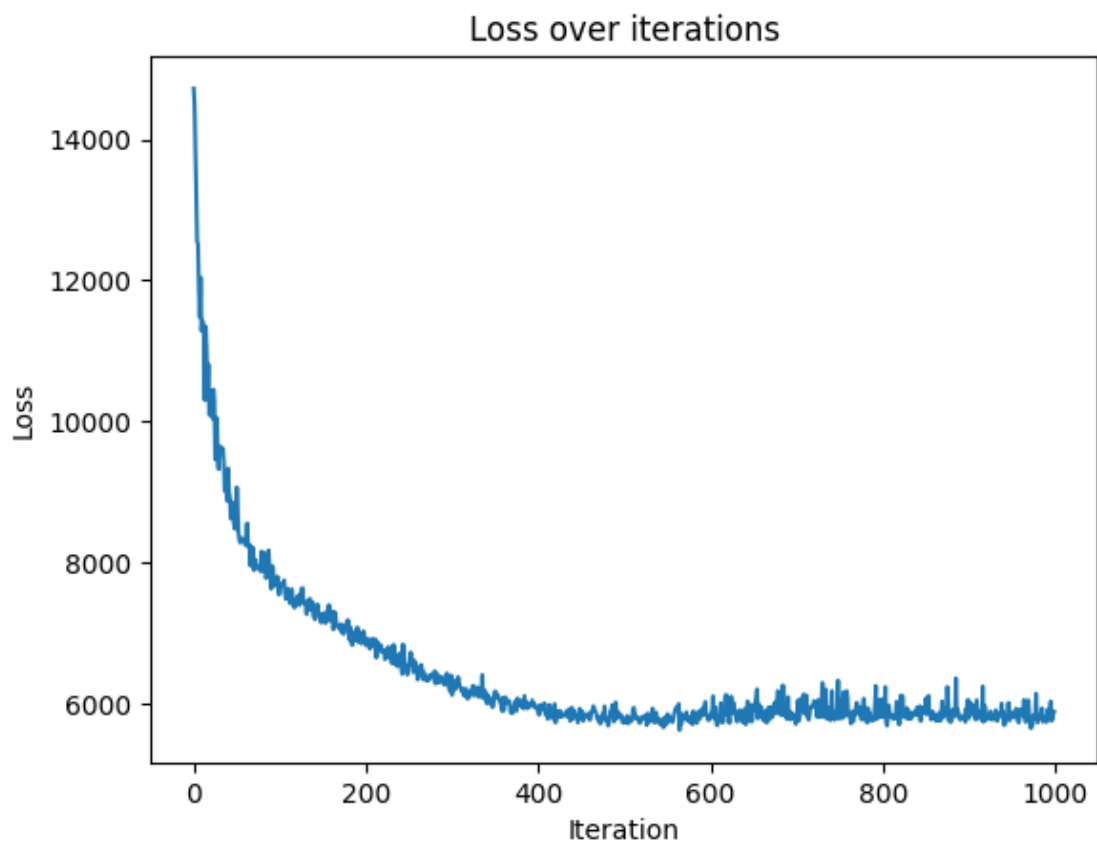
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Epoch 974 loss: 5711.5170  
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Epoch 977 loss: 5815.2233  
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Epoch 981 loss: 5851.2145

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Epoch 998 loss: 5870.0393  
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Updating parameters  
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Random sample



Interpolation in latent space



