

# Project 4

by Jiangyong Huang on Dec 3, 2022

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)

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    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.clone())

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
    sample = sample.clip(0, 1)
    # [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:

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```

        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: 14088.9264
Epoch 2 update:
Collecting gradients
Updating parameters
Epoch 2 loss: 13103.4685
Epoch 3 update:
Collecting gradients
Updating parameters
Epoch 3 loss: 12230.2179
Epoch 4 update:
Collecting gradients
Updating parameters
Epoch 4 loss: 11594.6001
Epoch 5 update:
Collecting gradients
Updating parameters
Epoch 5 loss: 11278.3279
Epoch 6 update:
Collecting gradients
Updating parameters
Epoch 6 loss: 10924.9395
Epoch 7 update:
Collecting gradients
Updating parameters
Epoch 7 loss: 10678.4846
Epoch 8 update:
Collecting gradients
Updating parameters
Epoch 8 loss: 10604.7773
Epoch 9 update:
```

Collecting gradients  
Updating parameters  
Epoch 9 loss: 10419.3426  
Epoch 10 update:  
Collecting gradients  
Updating parameters  
Epoch 10 loss: 10320.9698  
Epoch 11 update:  
Collecting gradients  
Updating parameters  
Epoch 11 loss: 10260.6475  
Epoch 12 update:  
Collecting gradients  
Updating parameters  
Epoch 12 loss: 10188.0520  
Epoch 13 update:  
Collecting gradients  
Updating parameters  
Epoch 13 loss: 10099.7384  
Epoch 14 update:  
Collecting gradients  
Updating parameters  
Epoch 14 loss: 9986.2071  
Epoch 15 update:  
Collecting gradients  
Updating parameters  
Epoch 15 loss: 9836.9175  
Epoch 16 update:  
Collecting gradients  
Updating parameters  
Epoch 16 loss: 9840.9277  
Epoch 17 update:  
Collecting gradients  
Updating parameters  
Epoch 17 loss: 9798.0469  
Epoch 18 update:  
Collecting gradients  
Updating parameters  
Epoch 18 loss: 9721.2092  
Epoch 19 update:  
Collecting gradients  
Updating parameters  
Epoch 19 loss: 9624.6802  
Epoch 20 update:  
Collecting gradients  
Updating parameters  
Epoch 20 loss: 9507.1528  
Epoch 21 update:



Collecting gradients  
Updating parameters  
Epoch 21 loss: 9329.1274  
Epoch 22 update:  
Collecting gradients  
Updating parameters  
Epoch 22 loss: 9343.1540  
Epoch 23 update:  
Collecting gradients  
Updating parameters  
Epoch 23 loss: 9274.1786  
Epoch 24 update:  
Collecting gradients  
Updating parameters  
Epoch 24 loss: 9101.8612  
Epoch 25 update:  
Collecting gradients  
Updating parameters  
Epoch 25 loss: 9170.4559  
Epoch 26 update:  
Collecting gradients  
Updating parameters  
Epoch 26 loss: 9109.2501  
Epoch 27 update:  
Collecting gradients  
Updating parameters  
Epoch 27 loss: 9044.2132  
Epoch 28 update:  
Collecting gradients  
Updating parameters  
Epoch 28 loss: 9007.6875  
Epoch 29 update:  
Collecting gradients  
Updating parameters  
Epoch 29 loss: 9008.5200  
Epoch 30 update:  
Collecting gradients  
Updating parameters  
Epoch 30 loss: 8910.8339  
Epoch 31 update:  
Collecting gradients  
Updating parameters  
Epoch 31 loss: 8833.4569  
Epoch 32 update:  
Collecting gradients  
Updating parameters  
Epoch 32 loss: 8856.4652  
Epoch 33 update:

Collecting gradients  
Updating parameters  
Epoch 33 loss: 8811.8224  
Epoch 34 update:  
Collecting gradients  
Updating parameters  
Epoch 34 loss: 8879.1914  
Epoch 35 update:  
Collecting gradients  
Updating parameters  
Epoch 35 loss: 8709.9898  
Epoch 36 update:  
Collecting gradients  
Updating parameters  
Epoch 36 loss: 8891.7944  
Epoch 37 update:  
Collecting gradients  
Updating parameters  
Epoch 37 loss: 8480.4003  
Epoch 38 update:  
Collecting gradients  
Updating parameters  
Epoch 38 loss: 8684.5438  
Epoch 39 update:  
Collecting gradients  
Updating parameters  
Epoch 39 loss: 8517.9165  
Epoch 40 update:  
Collecting gradients  
Updating parameters  
Epoch 40 loss: 8799.6954  
Epoch 41 update:  
Collecting gradients  
Updating parameters  
Epoch 41 loss: 8494.7990  
Epoch 42 update:  
Collecting gradients  
Updating parameters  
Epoch 42 loss: 8428.2677  
Epoch 43 update:  
Collecting gradients  
Updating parameters  
Epoch 43 loss: 8405.4058  
Epoch 44 update:  
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Updating parameters  
Epoch 44 loss: 8387.0823  
Epoch 45 update:

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Updating parameters  
Epoch 45 loss: 8510.2196  
Epoch 46 update:  
Collecting gradients  
Updating parameters  
Epoch 46 loss: 8761.6555  
Epoch 47 update:  
Collecting gradients  
Updating parameters  
Epoch 47 loss: 8636.0111  
Epoch 48 update:  
Collecting gradients  
Updating parameters  
Epoch 48 loss: 8640.6913  
Epoch 49 update:  
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Updating parameters  
Epoch 49 loss: 8619.2507  
Epoch 50 update:  
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Updating parameters  
Epoch 50 loss: 8415.6486  
Epoch 51 update:  
Collecting gradients  
Updating parameters  
Epoch 51 loss: 8245.2017  
Epoch 52 update:  
Collecting gradients  
Updating parameters  
Epoch 52 loss: 8132.3865  
Epoch 53 update:  
Collecting gradients  
Updating parameters  
Epoch 53 loss: 8020.5261  
Epoch 54 update:  
Collecting gradients  
Updating parameters  
Epoch 54 loss: 7976.4598  
Epoch 55 update:  
Collecting gradients  
Updating parameters  
Epoch 55 loss: 8083.0641  
Epoch 56 update:  
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Updating parameters  
Epoch 56 loss: 8031.6393  
Epoch 57 update:

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Updating parameters  
Epoch 57 loss: 8257.3594  
Epoch 58 update:  
Collecting gradients  
Updating parameters  
Epoch 58 loss: 8360.9917  
Epoch 59 update:  
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Epoch 59 loss: 8149.4457  
Epoch 60 update:  
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Updating parameters  
Epoch 60 loss: 8185.9775  
Epoch 61 update:  
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Epoch 61 loss: 8125.4318  
Epoch 62 update:  
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Updating parameters  
Epoch 62 loss: 8182.0954  
Epoch 63 update:  
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Updating parameters  
Epoch 63 loss: 8113.6246  
Epoch 64 update:  
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Epoch 64 loss: 8064.4549  
Epoch 65 update:  
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Epoch 65 loss: 7974.5505  
Epoch 66 update:  
Collecting gradients  
Updating parameters  
Epoch 66 loss: 7933.6414  
Epoch 67 update:  
Collecting gradients  
Updating parameters  
Epoch 67 loss: 7798.5133  
Epoch 68 update:  
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Epoch 68 loss: 7813.7507  
Epoch 69 update:

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Epoch 69 loss: 7700.7097  
Epoch 70 update:  
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Epoch 70 loss: 7732.1179  
Epoch 71 update:  
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Epoch 71 loss: 7717.9817  
Epoch 72 update:  
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Epoch 72 loss: 7606.6777  
Epoch 73 update:  
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Updating parameters  
Epoch 73 loss: 7615.1690  
Epoch 74 update:  
Collecting gradients  
Updating parameters  
Epoch 74 loss: 7581.2384  
Epoch 75 update:  
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Epoch 75 loss: 7660.7029  
Epoch 76 update:  
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Epoch 76 loss: 7549.6400  
Epoch 77 update:  
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Epoch 77 loss: 7444.2373  
Epoch 78 update:  
Collecting gradients  
Updating parameters  
Epoch 78 loss: 7458.2377  
Epoch 79 update:  
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Epoch 79 loss: 7417.1018  
Epoch 80 update:  
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Epoch 80 loss: 7543.6337  
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Epoch 81 loss: 7493.2535  
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Epoch 82 loss: 7477.4169  
Epoch 83 update:  
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Epoch 83 loss: 7445.5190  
Epoch 84 update:  
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Epoch 84 loss: 7276.5795  
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Epoch 85 loss: 7246.1444  
Epoch 86 update:  
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Epoch 86 loss: 7144.2584  
Epoch 87 update:  
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Epoch 87 loss: 7114.1060  
Epoch 88 update:  
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Epoch 88 loss: 7097.6317  
Epoch 89 update:  
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Epoch 89 loss: 7011.7354  
Epoch 90 update:  
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Epoch 90 loss: 6955.5299  
Epoch 91 update:  
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Epoch 91 loss: 6913.2248  
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Epoch 92 loss: 6907.2803  
Epoch 93 update:

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Epoch 93 loss: 6956.6922  
Epoch 94 update:  
Collecting gradients  
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Epoch 94 loss: 6927.4000  
Epoch 95 update:  
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Updating parameters  
Epoch 95 loss: 6958.1515  
Epoch 96 update:  
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Epoch 96 loss: 6954.9485  
Epoch 97 update:  
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Epoch 97 loss: 6979.9636  
Epoch 98 update:  
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Epoch 98 loss: 6871.9058  
Epoch 99 update:  
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Epoch 99 loss: 6865.2966  
Epoch 100 update:  
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Epoch 100 loss: 6861.8956  
Epoch 101 update:  
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Epoch 101 loss: 6905.3022  
Epoch 102 update:  
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Epoch 102 loss: 6848.7989  
Epoch 103 update:  
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Epoch 103 loss: 6923.9946  
Epoch 104 update:  
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Epoch 104 loss: 6906.7186  
Epoch 105 update:

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Epoch 105 loss: 6868.5077  
Epoch 106 update:  
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Epoch 106 loss: 6788.8433  
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Epoch 107 loss: 6831.5416  
Epoch 108 update:  
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Epoch 108 loss: 6713.1952  
Epoch 109 update:  
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Epoch 109 loss: 6758.0199  
Epoch 110 update:  
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Epoch 110 loss: 6836.0634  
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Epoch 111 loss: 7027.3512  
Epoch 112 update:  
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Epoch 112 loss: 6999.8731  
Epoch 113 update:  
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Epoch 113 loss: 6897.4537  
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Epoch 114 loss: 6805.5681  
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Epoch 116 loss: 6657.3029  
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Epoch 117 loss: 6634.6260  
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Epoch 118 loss: 6470.2023  
Epoch 119 update:  
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Epoch 119 loss: 6505.0676  
Epoch 120 update:  
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Epoch 120 loss: 6511.7805  
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Epoch 121 loss: 6568.1474  
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Epoch 122 loss: 6612.6337  
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Epoch 123 loss: 6537.4517  
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Epoch 126 loss: 6476.4082  
Epoch 127 update:  
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Epoch 127 loss: 6446.4878  
Epoch 128 update:  
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Epoch 128 loss: 6448.5896  
Epoch 129 update:

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Epoch 129 loss: 6349.9197  
Epoch 130 update:  
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Epoch 130 loss: 6245.4000  
Epoch 131 update:  
Collecting gradients  
Updating parameters  
Epoch 131 loss: 6278.8746  
Epoch 132 update:  
Collecting gradients  
Updating parameters  
Epoch 132 loss: 6279.0582  
Epoch 133 update:  
Collecting gradients  
Updating parameters  
Epoch 133 loss: 6217.1834  
Epoch 134 update:  
Collecting gradients  
Updating parameters  
Epoch 134 loss: 6171.3575  
Epoch 135 update:  
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Epoch 135 loss: 6121.1088  
Epoch 136 update:  
Collecting gradients  
Updating parameters  
Epoch 136 loss: 6061.2101  
Epoch 137 update:  
Collecting gradients  
Updating parameters  
Epoch 137 loss: 6067.3360  
Epoch 138 update:  
Collecting gradients  
Updating parameters  
Epoch 138 loss: 6124.5755  
Epoch 139 update:  
Collecting gradients  
Updating parameters  
Epoch 139 loss: 6062.7329  
Epoch 140 update:  
Collecting gradients  
Updating parameters  
Epoch 140 loss: 6083.7512  
Epoch 141 update:

Collecting gradients  
Updating parameters  
Epoch 141 loss: 6068.8024  
Epoch 142 update:  
Collecting gradients  
Updating parameters  
Epoch 142 loss: 6087.9688  
Epoch 143 update:  
Collecting gradients  
Updating parameters  
Epoch 143 loss: 6155.8896  
Epoch 144 update:  
Collecting gradients  
Updating parameters  
Epoch 144 loss: 6175.0555  
Epoch 145 update:  
Collecting gradients  
Updating parameters  
Epoch 145 loss: 6053.5675  
Epoch 146 update:  
Collecting gradients  
Updating parameters  
Epoch 146 loss: 5934.6085  
Epoch 147 update:  
Collecting gradients  
Updating parameters  
Epoch 147 loss: 5997.2307  
Epoch 148 update:  
Collecting gradients  
Updating parameters  
Epoch 148 loss: 5906.9578  
Epoch 149 update:  
Collecting gradients  
Updating parameters  
Epoch 149 loss: 5926.5589  
Epoch 150 update:  
Collecting gradients  
Updating parameters  
Epoch 150 loss: 5915.7997  
Epoch 151 update:  
Collecting gradients  
Updating parameters  
Epoch 151 loss: 5935.0451  
Epoch 152 update:  
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Epoch 883 update:  
Collecting gradients  
Updating parameters  
Epoch 883 loss: 2154.1061  
Epoch 884 update:  
Collecting gradients  
Updating parameters  
Epoch 884 loss: 2239.7314  
Epoch 885 update:



Collecting gradients  
Updating parameters  
Epoch 885 loss: 2259.7638  
Epoch 886 update:  
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Updating parameters  
Epoch 886 loss: 2342.9627  
Epoch 887 update:  
Collecting gradients  
Updating parameters  
Epoch 887 loss: 2131.4613  
Epoch 888 update:  
Collecting gradients  
Updating parameters  
Epoch 888 loss: 2060.9293  
Epoch 889 update:  
Collecting gradients  
Updating parameters  
Epoch 889 loss: 2181.1413  
Epoch 890 update:  
Collecting gradients  
Updating parameters  
Epoch 890 loss: 2168.2538  
Epoch 891 update:  
Collecting gradients  
Updating parameters  
Epoch 891 loss: 2177.3138  
Epoch 892 update:  
Collecting gradients  
Updating parameters  
Epoch 892 loss: 2566.0977  
Epoch 893 update:  
Collecting gradients  
Updating parameters  
Epoch 893 loss: 2534.7476  
Epoch 894 update:  
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Updating parameters  
Epoch 894 loss: 2408.9004  
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Updating parameters  
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Epoch 907 loss: 2091.5647  
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Updating parameters  
Epoch 920 loss: 2157.1769  
Epoch 921 update:

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Epoch 921 loss: 2151.5632  
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Epoch 933 update:

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Updating parameters  
Epoch 941 loss: 2289.4714  
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Updating parameters  
Epoch 942 loss: 2316.8850  
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Updating parameters  
Epoch 943 loss: 2257.5771  
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Epoch 944 loss: 2292.5415  
Epoch 945 update:

Collecting gradients  
Updating parameters  
Epoch 945 loss: 2383.8119  
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Updating parameters  
Epoch 946 loss: 2268.8230  
Epoch 947 update:  
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Updating parameters  
Epoch 947 loss: 2297.6232  
Epoch 948 update:  
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Updating parameters  
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Updating parameters  
Epoch 949 loss: 2170.1113  
Epoch 950 update:  
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Updating parameters  
Epoch 950 loss: 2206.7495  
Epoch 951 update:  
Collecting gradients  
Updating parameters  
Epoch 951 loss: 2166.8302  
Epoch 952 update:  
Collecting gradients  
Updating parameters  
Epoch 952 loss: 2301.2164  
Epoch 953 update:  
Collecting gradients  
Updating parameters  
Epoch 953 loss: 2124.5906  
Epoch 954 update:  
Collecting gradients  
Updating parameters  
Epoch 954 loss: 2148.8892  
Epoch 955 update:  
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Updating parameters  
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Collecting gradients  
Updating parameters  
Epoch 956 loss: 2173.4291  
Epoch 957 update:

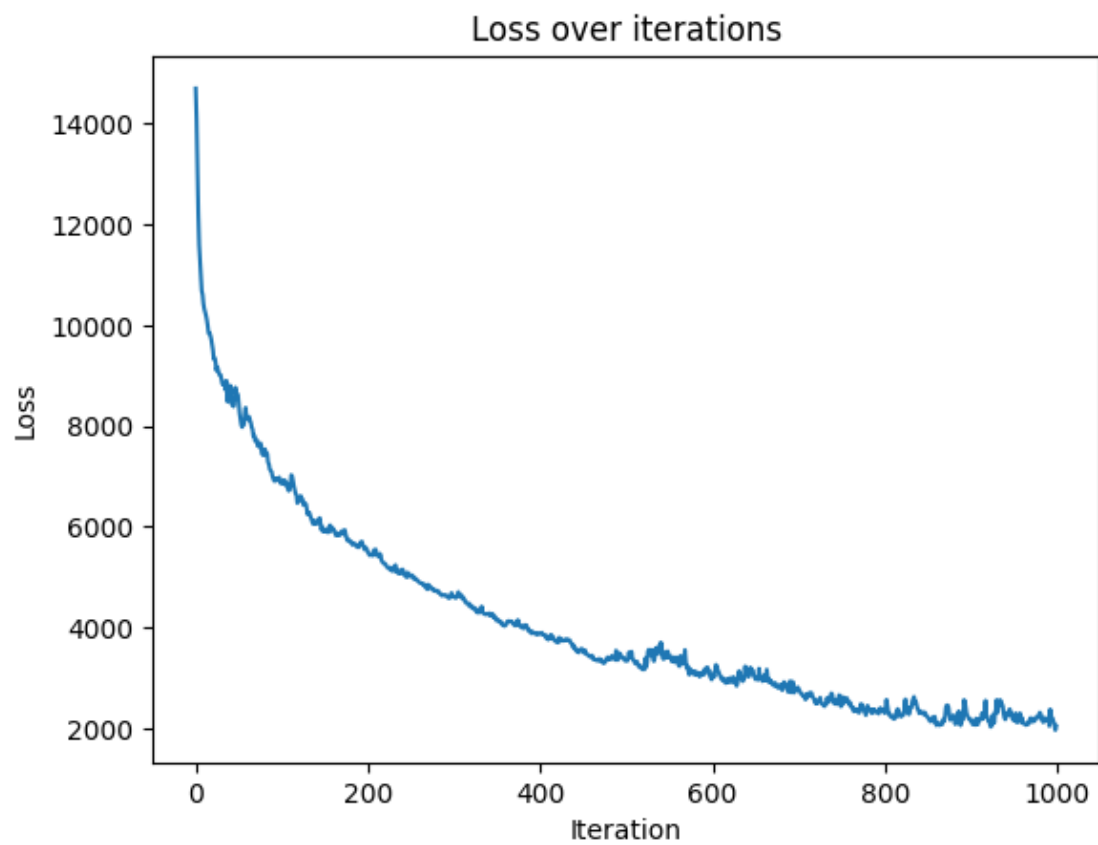
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Updating parameters  
Epoch 958 loss: 2132.1132  
Epoch 959 update:  
Collecting gradients  
Updating parameters  
Epoch 959 loss: 2217.4729  
Epoch 960 update:  
Collecting gradients  
Updating parameters  
Epoch 960 loss: 2110.4456  
Epoch 961 update:  
Collecting gradients  
Updating parameters  
Epoch 961 loss: 2096.3132  
Epoch 962 update:  
Collecting gradients  
Updating parameters  
Epoch 962 loss: 2098.3151  
Epoch 963 update:  
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Updating parameters  
Epoch 963 loss: 2092.1749  
Epoch 964 update:  
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Updating parameters  
Epoch 964 loss: 2067.4112  
Epoch 965 update:  
Collecting gradients  
Updating parameters  
Epoch 965 loss: 2096.3759  
Epoch 966 update:  
Collecting gradients  
Updating parameters  
Epoch 966 loss: 2080.7951  
Epoch 967 update:  
Collecting gradients  
Updating parameters  
Epoch 967 loss: 2136.2095  
Epoch 968 update:  
Collecting gradients  
Updating parameters  
Epoch 968 loss: 2109.7845  
Epoch 969 update:

Collecting gradients  
Updating parameters  
Epoch 969 loss: 2204.9117  
Epoch 970 update:  
Collecting gradients  
Updating parameters  
Epoch 970 loss: 2166.9613  
Epoch 971 update:  
Collecting gradients  
Updating parameters  
Epoch 971 loss: 2200.2651  
Epoch 972 update:  
Collecting gradients  
Updating parameters  
Epoch 972 loss: 2136.1229  
Epoch 973 update:  
Collecting gradients  
Updating parameters  
Epoch 973 loss: 2143.6076  
Epoch 974 update:  
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Epoch 974 loss: 2149.3872  
Epoch 975 update:  
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Updating parameters  
Epoch 976 loss: 2220.5516  
Epoch 977 update:  
Collecting gradients  
Updating parameters  
Epoch 977 loss: 2238.2019  
Epoch 978 update:  
Collecting gradients  
Updating parameters  
Epoch 978 loss: 2212.8310  
Epoch 979 update:  
Collecting gradients  
Updating parameters  
Epoch 979 loss: 2268.9045  
Epoch 980 update:  
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Epoch 980 loss: 2315.4568  
Epoch 981 update:

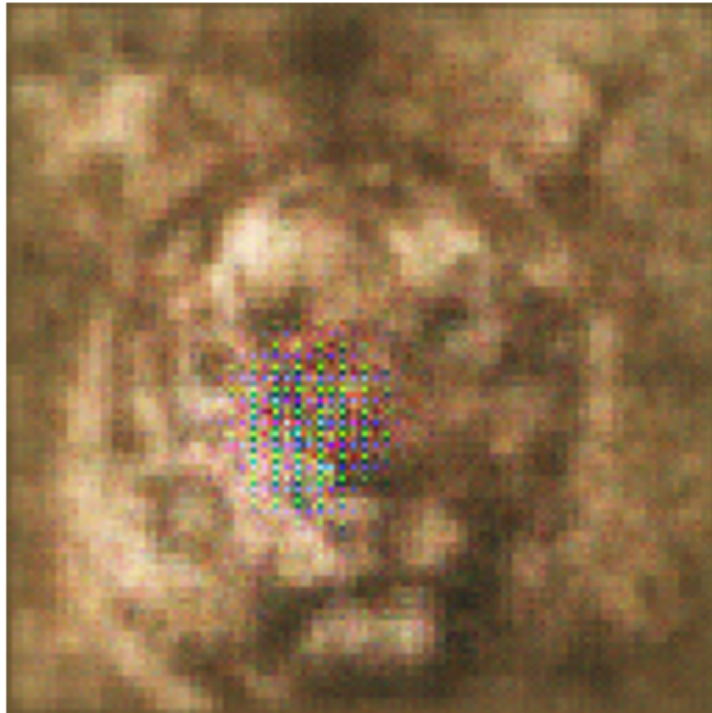


Collecting gradients  
Updating parameters  
Epoch 981 loss: 2290.1737  
Epoch 982 update:  
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Epoch 982 loss: 2181.3142  
Epoch 983 update:  
Collecting gradients  
Updating parameters  
Epoch 983 loss: 2171.7758  
Epoch 984 update:  
Collecting gradients  
Updating parameters  
Epoch 984 loss: 2123.0190  
Epoch 985 update:  
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Updating parameters  
Epoch 985 loss: 2211.6554  
Epoch 986 update:  
Collecting gradients  
Updating parameters  
Epoch 986 loss: 2150.0679  
Epoch 987 update:  
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Updating parameters  
Epoch 987 loss: 2168.5659  
Epoch 988 update:  
Collecting gradients  
Updating parameters  
Epoch 988 loss: 2166.4415  
Epoch 989 update:  
Collecting gradients  
Updating parameters  
Epoch 989 loss: 2209.4887  
Epoch 990 update:  
Collecting gradients  
Updating parameters  
Epoch 990 loss: 2197.9036  
Epoch 991 update:  
Collecting gradients  
Updating parameters  
Epoch 991 loss: 2049.6125  
Epoch 992 update:  
Collecting gradients  
Updating parameters  
Epoch 992 loss: 2380.7288  
Epoch 993 update:

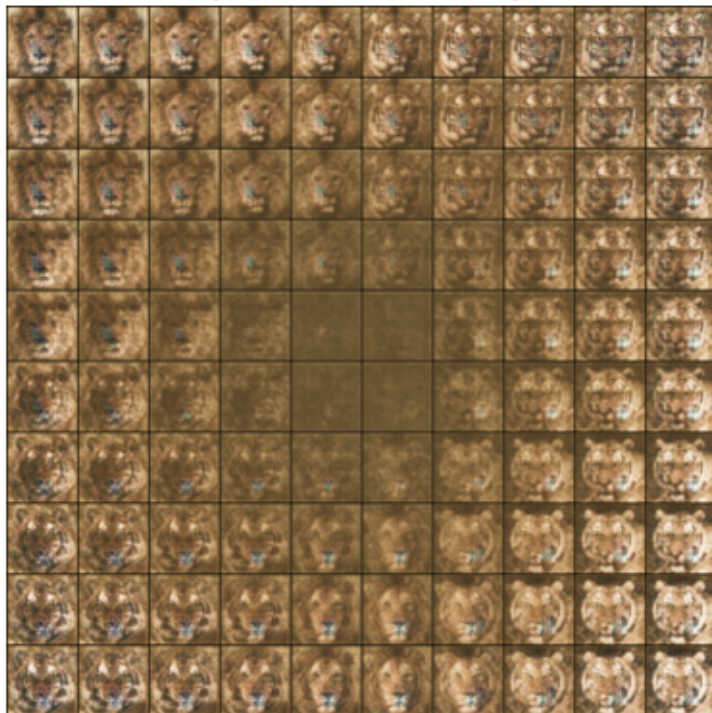
Collecting gradients  
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Epoch 993 loss: 2141.3279  
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Epoch 994 loss: 2222.5043  
Epoch 995 update:  
Collecting gradients  
Updating parameters  
Epoch 995 loss: 2154.4284  
Epoch 996 update:  
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Updating parameters  
Epoch 996 loss: 2140.2492  
Epoch 997 update:  
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Updating parameters  
Epoch 997 loss: 2044.8970  
Epoch 998 update:  
Collecting gradients  
Updating parameters  
Epoch 998 loss: 1966.5646  
Epoch 999 update:  
Collecting gradients  
Updating parameters  
Epoch 999 loss: 2049.1398



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: 14719.0267
Epoch 1 update:
Collecting gradients
Updating parameters
Epoch 1 loss: 14380.0411
Epoch 2 update:
Collecting gradients
Updating parameters
Epoch 2 loss: 13614.5272
Epoch 3 update:
Collecting gradients
Updating parameters
Epoch 3 loss: 12397.3314
Epoch 4 update:
Collecting gradients
Updating parameters
Epoch 4 loss: 11809.6816
Epoch 5 update:
Collecting gradients
Updating parameters
Epoch 5 loss: 11340.2380
Epoch 6 update:
Collecting gradients
Updating parameters
Epoch 6 loss: 10889.2538
Epoch 7 update:
Collecting gradients
Updating parameters
Epoch 7 loss: 10312.6388
Epoch 8 update:
Collecting gradients
Updating parameters
Epoch 8 loss: 10571.4486
Epoch 9 update:
Collecting gradients
Updating parameters
Epoch 9 loss: 9999.2645
```

Epoch 10 update:  
Collecting gradients  
Updating parameters  
Epoch 10 loss: 9882.8931  
Epoch 11 update:  
Collecting gradients  
Updating parameters  
Epoch 11 loss: 9641.6105  
Epoch 12 update:  
Collecting gradients  
Updating parameters  
Epoch 12 loss: 9716.9286  
Epoch 13 update:  
Collecting gradients  
Updating parameters  
Epoch 13 loss: 9503.8839  
Epoch 14 update:  
Collecting gradients  
Updating parameters  
Epoch 14 loss: 9531.9989  
Epoch 15 update:  
Collecting gradients  
Updating parameters  
Epoch 15 loss: 9587.4835  
Epoch 16 update:  
Collecting gradients  
Updating parameters  
Epoch 16 loss: 9141.4463  
Epoch 17 update:  
Collecting gradients  
Updating parameters  
Epoch 17 loss: 9128.6594  
Epoch 18 update:  
Collecting gradients  
Updating parameters  
Epoch 18 loss: 8903.8576  
Epoch 19 update:  
Collecting gradients  
Updating parameters  
Epoch 19 loss: 8757.9154  
Epoch 20 update:  
Collecting gradients  
Updating parameters  
Epoch 20 loss: 8881.6733  
Epoch 21 update:  
Collecting gradients  
Updating parameters  
Epoch 21 loss: 8741.1378

Epoch 22 update:  
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Updating parameters  
Epoch 22 loss: 8861.0257  
Epoch 23 update:  
Collecting gradients  
Updating parameters  
Epoch 23 loss: 8938.8741  
Epoch 24 update:  
Collecting gradients  
Updating parameters  
Epoch 24 loss: 8835.4178  
Epoch 25 update:  
Collecting gradients  
Updating parameters  
Epoch 25 loss: 9206.4424  
Epoch 26 update:  
Collecting gradients  
Updating parameters  
Epoch 26 loss: 8664.0998  
Epoch 27 update:  
Collecting gradients  
Updating parameters  
Epoch 27 loss: 8568.4539  
Epoch 28 update:  
Collecting gradients  
Updating parameters  
Epoch 28 loss: 8536.2600  
Epoch 29 update:  
Collecting gradients  
Updating parameters  
Epoch 29 loss: 8436.4444  
Epoch 30 update:  
Collecting gradients  
Updating parameters  
Epoch 30 loss: 8386.7247  
Epoch 31 update:  
Collecting gradients  
Updating parameters  
Epoch 31 loss: 8362.5619  
Epoch 32 update:  
Collecting gradients  
Updating parameters  
Epoch 32 loss: 8293.8813  
Epoch 33 update:  
Collecting gradients  
Updating parameters  
Epoch 33 loss: 8402.3979

Epoch 34 update:  
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Updating parameters  
Epoch 34 loss: 8401.7150  
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Updating parameters  
Epoch 35 loss: 8242.5721  
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Epoch 42 loss: 8013.0013  
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Epoch 43 loss: 7864.5166  
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Epoch 44 loss: 7877.8981  
Epoch 45 update:  
Collecting gradients  
Updating parameters  
Epoch 45 loss: 7847.5923



Epoch 46 update:  
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Updating parameters  
Epoch 46 loss: 7718.0627  
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Updating parameters  
Epoch 47 loss: 7725.2005  
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Epoch 57 loss: 7472.9228

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Epoch 60 loss: 7475.5665  
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Updating parameters  
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Updating parameters  
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Updating parameters  
Epoch 81 loss: 7134.8855

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Epoch 93 loss: 6714.3791

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Epoch 944 loss: 3538.5316  
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Updating parameters  
Epoch 945 loss: 3542.3537

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Epoch 957 loss: 3585.5775

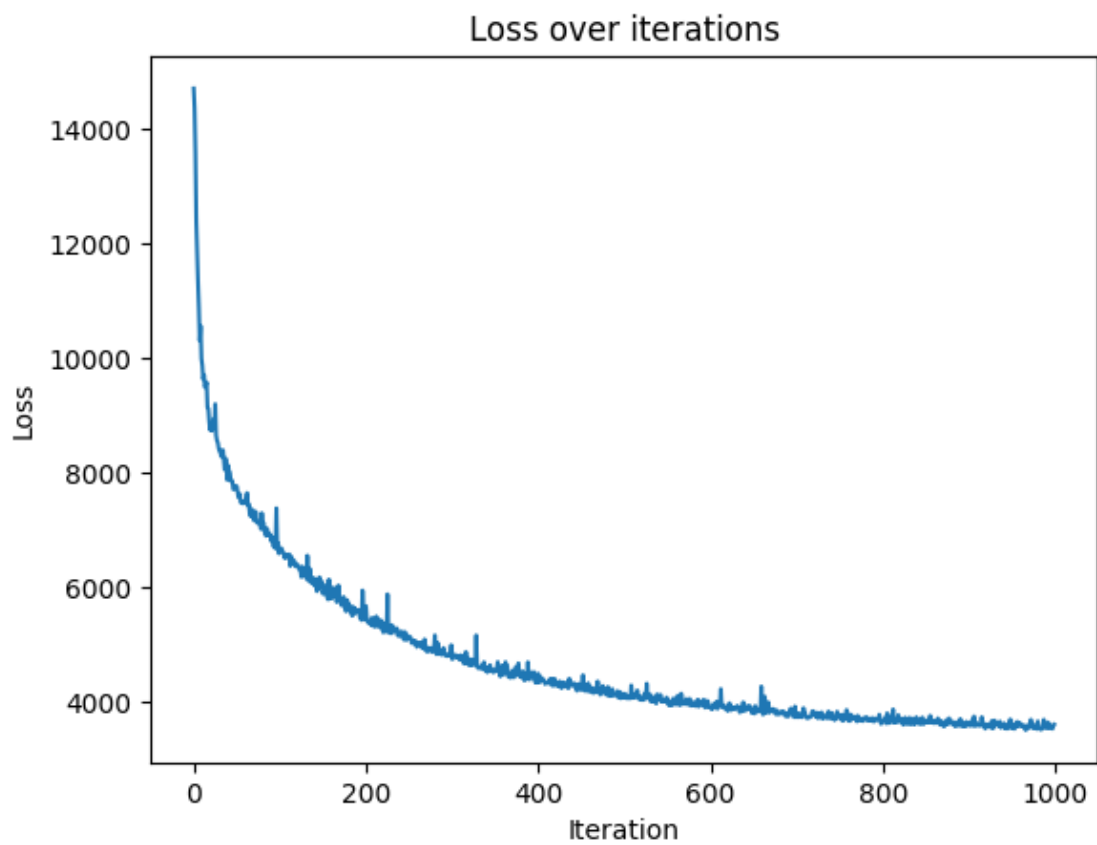
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Epoch 978 loss: 3545.0968  
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Epoch 979 loss: 3534.5225  
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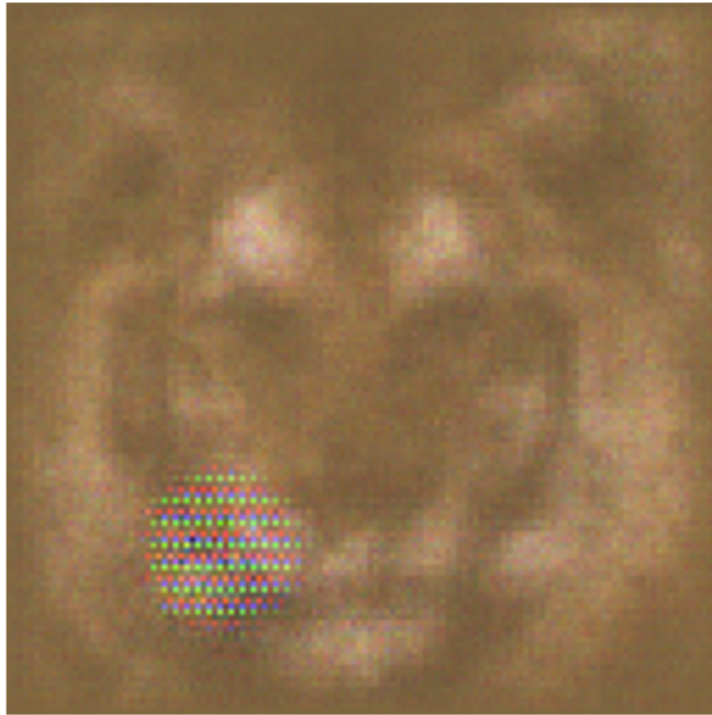
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Epoch 993 loss: 3545.3507

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Epoch 996 loss: 3577.2305  
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Updating parameters  
Epoch 997 loss: 3537.5226  
Epoch 998 update:  
Collecting gradients  
Updating parameters  
Epoch 998 loss: 3586.5791  
Epoch 999 update:  
Collecting gradients  
Updating parameters  
Epoch 999 loss: 3610.6932





Random sample



Interpolation in latent space

