In [ ]:

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from __future__ import print_function
import argparse
import torch
import torch.utils.data
from torch import nn, optim
from torchvision import datasets, transforms
from torchvision.utils import save_image
from IPython.display import Image, display
import matplotlib.pyplot as plt
import os

if not os.path.exists('results'):
    os.mkdir('results')

batch_size = 100
latent_size = 20

cuda = torch.cuda.is_available()
device = torch.device("cuda" if cuda else "cpu")

kwargs = {'num_workers': 1, 'pin_memory': True} if cuda else {}
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('../data', train=True, download=True,
                   transform=transforms.ToTensor()),
    batch_size=batch_size, shuffle=True, **kwargs)
test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('../data', train=False, transform=transforms.ToTensor()),
    batch_size=batch_size, shuffle=True, **kwargs)


class Generator(nn.Module):
    def __init__(self):
      super(Generator, self).__init__()
      self.gen = nn.Sequential(
          nn.Linear(latent_size, 400),
          nn.ReLU(True),
          nn.Linear(400, 784),
          nn.Sigmoid())

    def forward(self, z):
      return self.gen(z).view(-1, 28, 28)

class Discriminator(nn.Module):
    def __init__(self):
      super(Discriminator, self).__init__()
      self.disc = nn.Sequential(
          nn.Linear(784, 400),
          nn.ReLU(True),
          nn.Linear(400, 1),
          nn.Sigmoid()
      )

    def forward(self, x):
      x = x.view(-1, 784)
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      return self.disc(x)

def train(generator, generator_optimizer, discriminator, discriminator_optim
    total_gen_loss = 0
    total_disc_loss = 0

    criterion = nn.BCELoss()

    generator.train()
    discriminator.train()

    for _, (real_images, _) in enumerate(train_loader):
      real_images = real_images.to(device)
      batch_size = real_images.size(0)

      real_labels = torch.ones(batch_size, 1).to(device)
      fake_labels = torch.zeros(batch_size, 1).to(device)
      z = torch.randn(batch_size, latent_size).to(device)

      generator_optimizer.zero_grad()
      fake_images = generator(z)
      outputs = discriminator(fake_images)
      gen_loss = criterion(outputs, real_labels)
      gen_loss.backward()
      generator_optimizer.step()

      discriminator_optimizer.zero_grad()
      outputs = discriminator(real_images)
      real_loss = criterion(outputs, real_labels)
      outputs = discriminator(fake_images.detach())
      fake_loss = criterion(outputs, fake_labels)
      disc_loss = real_loss + fake_loss
      disc_loss.backward()
      discriminator_optimizer.step()

      total_gen_loss += gen_loss.item()
      total_disc_loss += disc_loss.item()

    avg_generator_loss = total_gen_loss / len(train_loader.dataset)
    avg_discriminator_loss = total_disc_loss / len(train_loader.dataset)
    return avg_generator_loss, avg_discriminator_loss

def test(generator, discriminator):
    total_gen_loss = 0
    total_disc_loss = 0

    criterion = nn.BCELoss()

    generator.eval()
    discriminator.eval()

    with torch.no_grad():
      for _, (real_images, _) in enumerate(test_loader):
        real_images = real_images.to(device)
        batch_size = real_images.size(0)
```

```
        real_labels = torch.ones(batch_size, 1).to(device)
        fake_labels = torch.zeros(batch_size, 1).to(device)

        z = torch.randn(batch_size, latent_size).to(device)

        fake_images = generator(z)

        outputs = discriminator(fake_images)
        gen_loss = criterion(outputs, real_labels)

        outputs = discriminator(fake_images)
        fake_loss = criterion(outputs, fake_labels)

        outputs = discriminator(real_images)
        real_loss = criterion(outputs, real_labels)

        disc_loss = real_loss + fake_loss

        total_gen_loss += gen_loss.item()
        total_disc_loss += disc_loss.item()

    avg_generator_loss = total_gen_loss / len(test_loader.dataset)
    avg_discriminator_loss = total_disc_loss / len(test_loader.dataset)

    return avg_generator_loss, avg_discriminator_loss


epochs = 50

discriminator_avg_train_losses = []
discriminator_avg_test_losses = []
generator_avg_train_losses = []
generator_avg_test_losses = []

generator = Generator().to(device)
discriminator = Discriminator().to(device)

generator_optimizer = optim.Adam(generator.parameters(), lr=1e-3)
discriminator_optimizer = optim.Adam(discriminator.parameters(), lr=1e-3)

for epoch in range(1, epochs + 1):
    generator_avg_train_loss, discriminator_avg_train_loss = train(generator
    generator_avg_test_loss, discriminator_avg_test_loss = test(generator, d

    discriminator_avg_train_losses.append(discriminator_avg_train_loss)
    generator_avg_train_losses.append(generator_avg_train_loss)
    discriminator_avg_test_losses.append(discriminator_avg_test_loss)
    generator_avg_test_losses.append(generator_avg_test_loss)

    with torch.no_grad():
        sample = torch.randn(64, latent_size).to(device)
        sample = generator(sample).cpu()
        save_image(sample.view(64, 1, 28, 28),
                   'results/sample_' + str(epoch) + '.png')
        print('Epoch #' + str(epoch))
        display(Image('results/sample_' + str(epoch) + '.png'))
```

```
        print('\n')

plt.plot(discriminator_avg_train_losses)
plt.plot(generator_avg_train_losses)
plt.title('Training Loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Disc','Gen'], loc='upper right')
plt.show()

plt.plot(discriminator_avg_test_losses)
plt.plot(generator_avg_test_losses)
plt.title('Test Loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Disc','Gen'], loc='upper right')
plt.show()
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz to
../data/MNIST/raw/train-images-idx3-ubyte.gz
100%|██████████| 9912422/9912422 [00:00<00:00, 229375641.33it/s]
Extracting ../data/MNIST/raw/train-images-idx3-ubyte.gz to ../data/MNIST/raw

Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz
Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz to
../data/MNIST/raw/train-labels-idx1-ubyte.gz
100%|██████████| 28881/28881 [00:00<00:00, 26553199.00it/s]
Extracting ../data/MNIST/raw/train-labels-idx1-ubyte.gz to ../data/MNIST/raw

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Downloading http://yann.lecun.com/exdb/mnist/t10k-images-idx3-ubyte.gz to
../data/MNIST/raw/t10k-images-idx3-ubyte.gz
100%|██████████| 1648877/1648877 [00:00<00:00, 67874724.18it/s]
Extracting ../data/MNIST/raw/t10k-images-idx3-ubyte.gz to ../data/MNIST/raw

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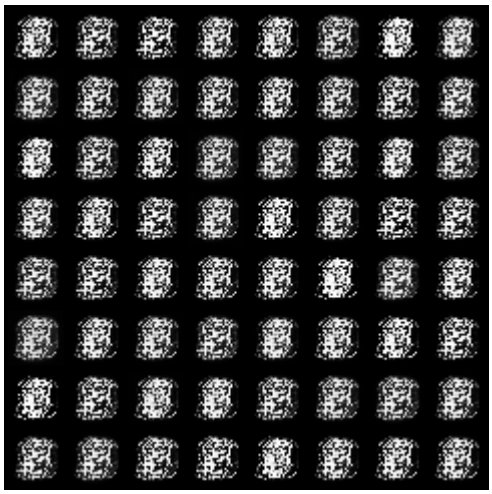
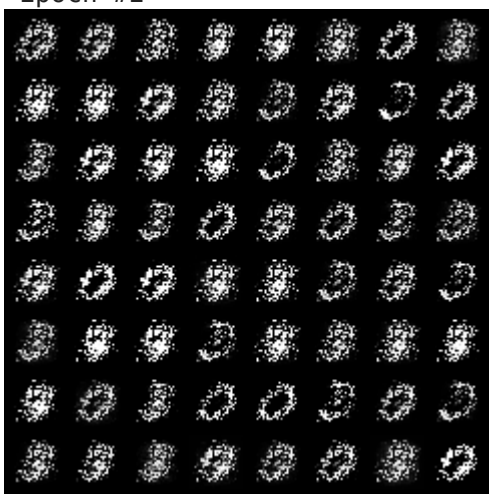
Downloading http://yann.lecun.com/exdb/mnist/t10k-labels-idx1-ubyte.gz to
../data/MNIST/raw/t10k-labels-idx1-ubyte.gz
100%|██████████| 4542/4542 [00:00<00:00, 7875373.61it/s]
Extracting ../data/MNIST/raw/t10k-labels-idx1-ubyte.gz to ../data/MNIST/raw

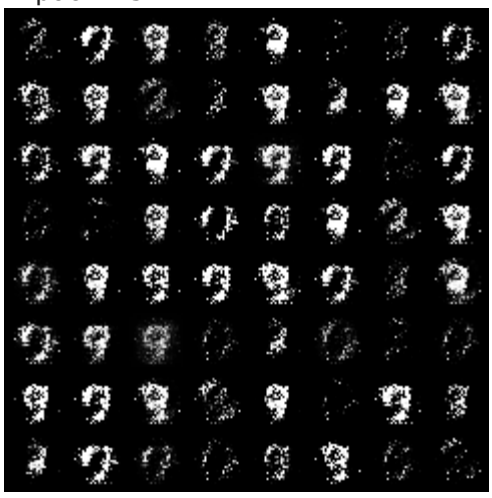
Epoch #1
```



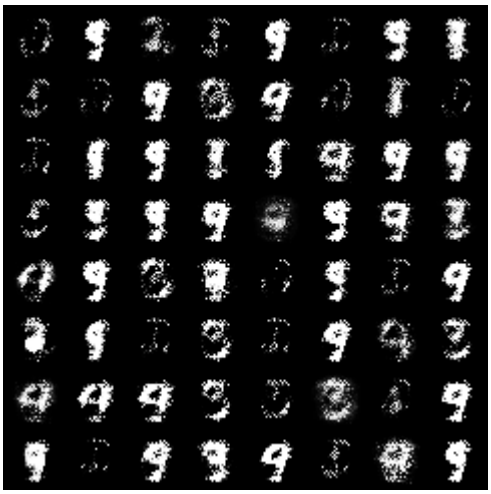
Epoch #2



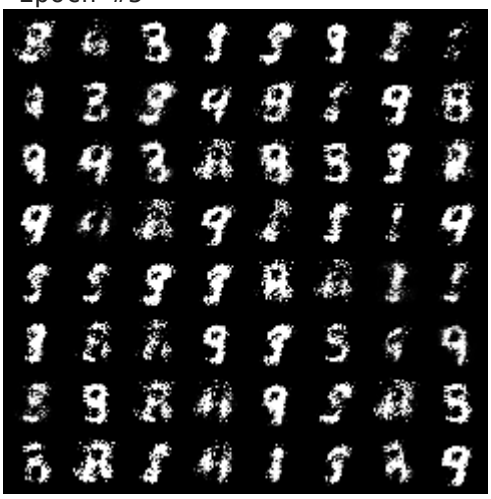
Epoch #3



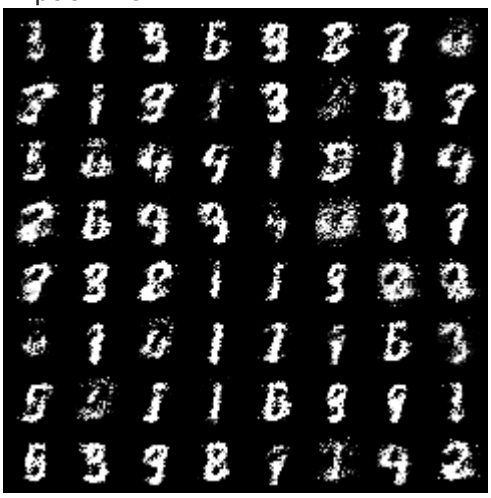
Epoch #4



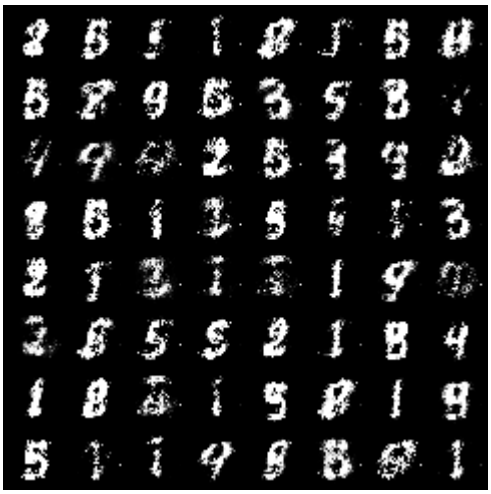
Epoch #5



Epoch #6



Epoch #7

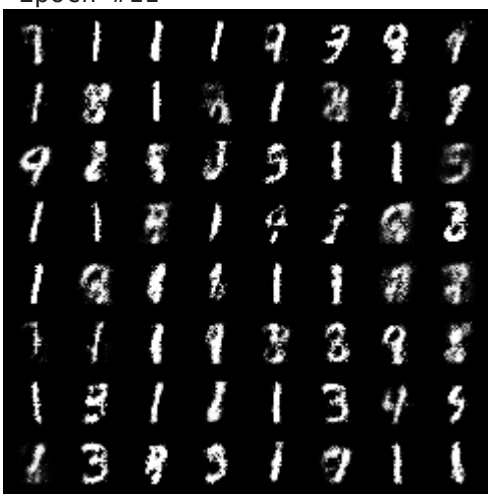


Epoch #8

Epoch #9

Epoch #10

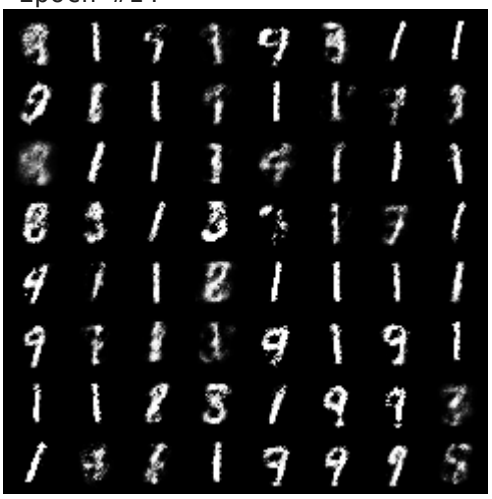
Epoch #11



Epoch #12

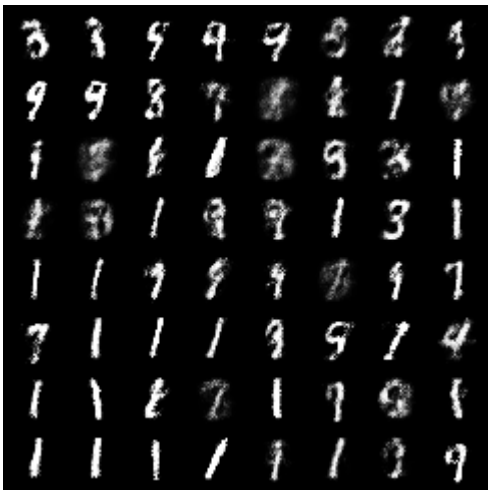
Epoch #13

Epoch #14



Epoch #15

Epoch #16



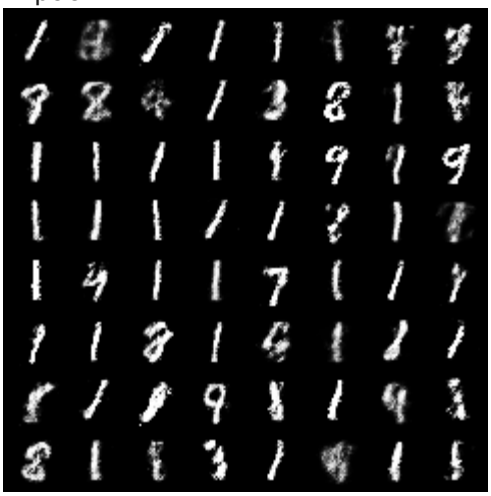
Epoch #17

Epoch #18

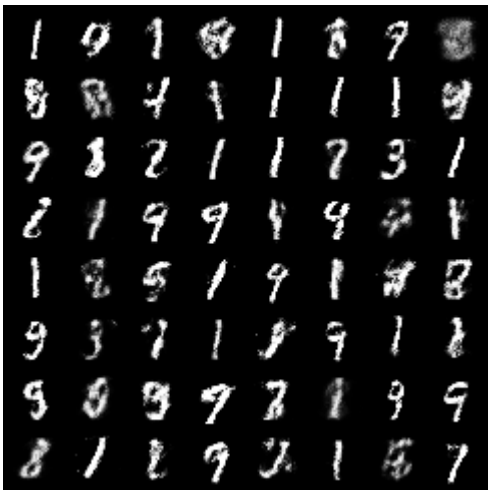
Epoch #19

Epoch #20

Epoch #21



Epoch #22



Epoch #23

Epoch #24

Epoch #25

Epoch #26

Epoch #27

Epoch #28

Epoch #29

Epoch #30

Epoch #31

Epoch #32

Epoch #33

Epoch #34

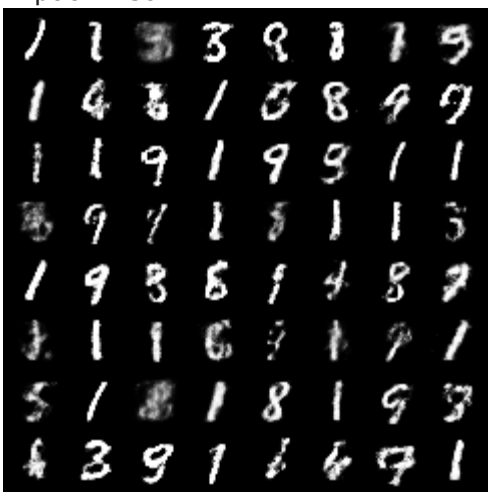
Epoch #35

Epoch #36

Epoch #37

Epoch #38

Epoch #39



Epoch #40

Epoch #41

Epoch #42

Epoch #43

Epoch #44

Epoch #45

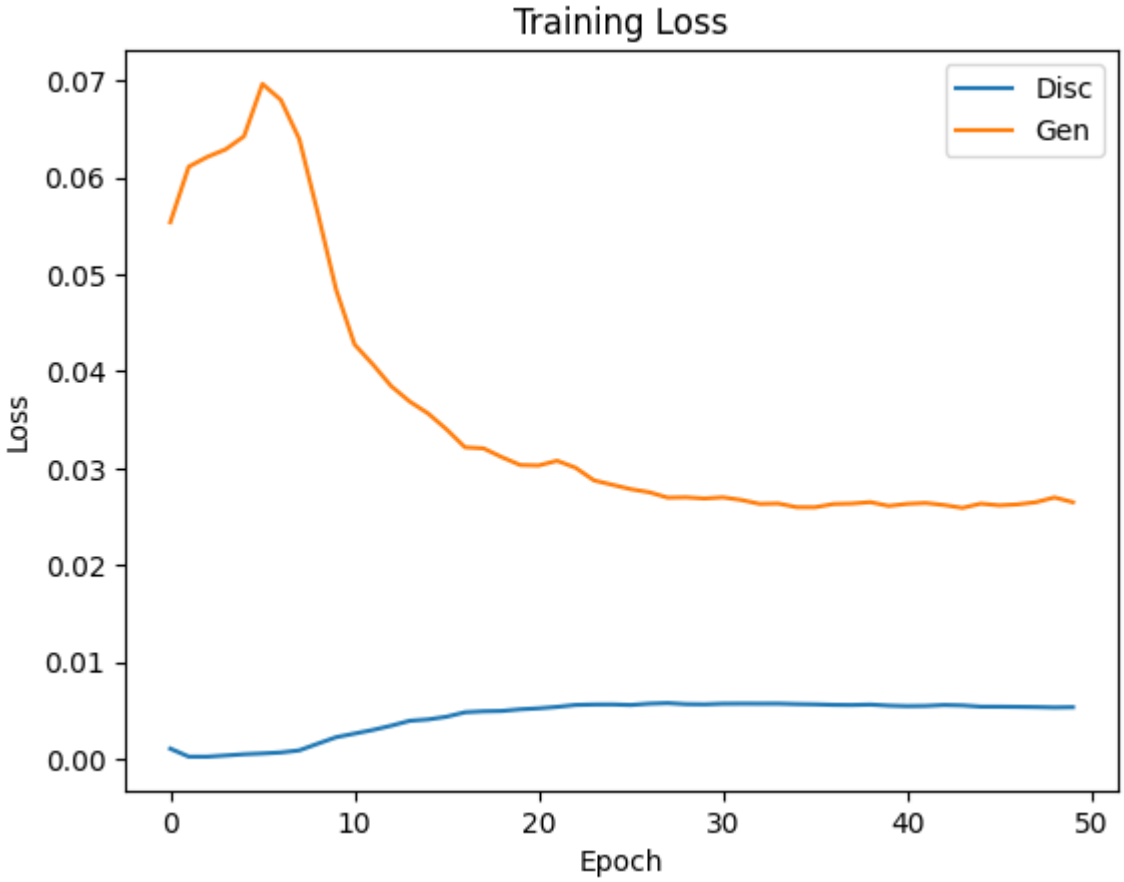
Epoch #46

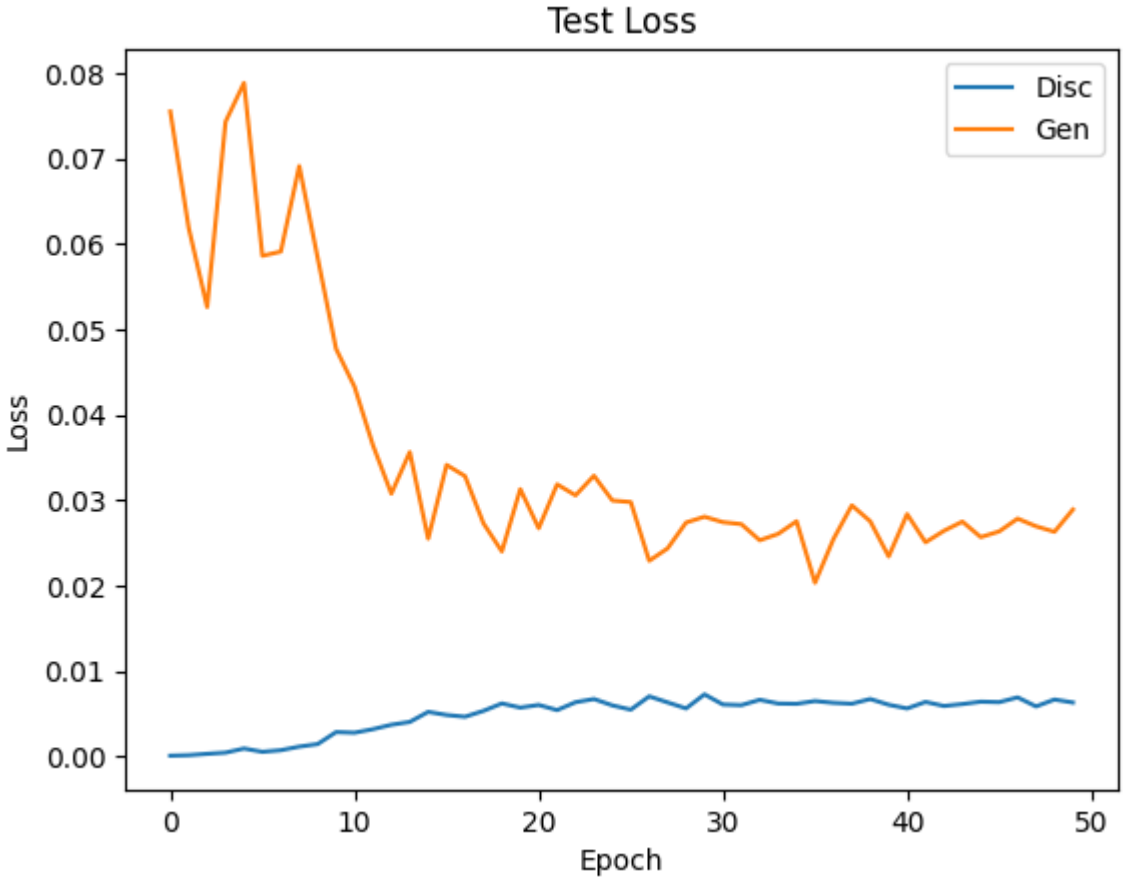
Epoch #47

Epoch #48

Epoch #49

Epoch #50


Training Loss
Disc
Gen
Loss
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Epoch


Test Loss
Disc
Gen
Loss
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
10
20
30
40
50
Epoch