

Generative Adversarial Networks (GAN)

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21BAI1007

Aim

1. Implement Vanilla GAN to generate images of the MNIST Handwritten digits dataset.
2. Implement Vanilla GAN to generate images of the CIFAR-10 image dataset.

Code and Output for Aim (i)

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> 2IBA1007_label_sample.ipynb
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Vanilla GAN on MNIST Dataset

Goudham Krishnan · 21BA11007

import torch
import torch.nn as nn
import torch.optim as optim
from torchvision.utils import save_image
from torchvision.datasets import MNIST
from torchvision.utils import make_grid
from torch.utils.data import DataLoader
import imageio
from torchvision.transforms.functional import pil_to_image

[ ] transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.5,), (0.5,))
])

to_image = transforms.ToPILImage()
trainer = MNISTTrainer(data_loader=train_loader, download_root=transform.transform)
trainloader = DataLoader(trainset, batch_size=64, shuffle=True)

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class generator(nn.Module):
    def __init__(self):
        super(generator, self).__init__()
        self.n_features = 128
        self.n_out = 784
        self.fc0 = nn.Sequential(
            nn.Linear(self.n_features, 256),
            nn.ReLU(True))

        self.fc1 = nn.Sequential(
            nn.Linear(256, 512),
            nn.ReLU(True))

        self.fc2 = nn.Sequential(
            nn.Linear(512, 1024),
            nn.ReLU(True))

        self.fc3 = nn.Sequential(
            nn.Linear(1024, self.n_out),
            nn.Tanh())

    def forward(self, x):
        x = self.fc0(x)
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        x = x.view(-1, 1, 28, 28)
        return x

class Discriminator(nn.Module):
    def __init__(self):
        super(Discriminator, self).__init__()
        self.n_in = 784
        self.n_out = 1
        self.fc0 = nn.Sequential(
            nn.Linear(self.n_in, 1024),
            nn.ReLU(True),
            nn.Dropout(0.3))

        self.fc1 = nn.Sequential(
            nn.Linear(1024, 512),
            nn.ReLU(True),
            nn.Dropout(0.3))

        self.fc2 = nn.Sequential(
            nn.Linear(512, 256),
            nn.ReLU(True),
            nn.Dropout(0.3))

        self.fc3 = nn.Sequential(
            nn.Linear(256, self.n_out),
            nn.Sigmoid())

```

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self.fc3 = nn.Sequential(
    nn.Linear(256, self.n_out),
    nn.Sigmoid())

def forward(self, x):
    x = x.view(-1, 784)
    x = self.fc0(x)
    x = self.fc1(x)
    x = self.fc2(x)
    x = self.fc3(x)
    return x

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

g_optimizer = optim.Adam(generator.parameters(), lr=0.001)
d_optimizer = optim.Adam(discriminator.parameters(), lr=0.001)

g_losses = []
d_losses = []
images = []

criterion = nn.BCELoss()

def make_noise(n_features=784):
    return Variable(torch.randn(1, n_features)).to(device)

def make_one(size):
    data = Variable(torch.ones(size, 1))
    return data.to(device)

def make_zero(size):
    data = Variable(torch.zeros(size, 1))
    return data.to(device)

def train_discriminator(optimizer, real_data, fake_data):
    n = real_data.size(0)
    optimizer.zero_grad()

    prediction_real = discriminator(real_data)
    error_real = criterion(prediction_real, make_one(n))
    error_real.backward()

    prediction_fake = discriminator(fake_data)
    error_fake = criterion(prediction_fake, make_zero(n))
    error_fake.backward()
    optimizer.step()

    return error_real + error_fake

```

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return error_real + error_fake

def train_generator(optimizer, fake_data):
    n = fake_data.size(0)
    optimizer.zero_grad()

    prediction = discriminator(fake_data)
    error = criterion(prediction, make_one(n))
    error.backward()
    optimizer.step()

    return error

num_epochs = 25
k = 1
test_noise = noise(64)

generator.train()
discriminator.train()
for epoch in range(num_epochs):
    g_error = 0.0
    d_error = 0.0
    for i, data in enumerate(trainloader):
        img, _ = data
        n = len(img)
        for j in range(k):
            fake_data = generator(noise(n)).detach()
            real_data = img.to(device)
            d_error += train_discriminator(d_optimizer, real_data, fake_data)
            fake_data = generator(noise(n))
            g_error += train_generator(g_optimizer, fake_data)

        img = generator(test_noise.cpu()).detach()
        img = make_grid(img)
        images.append(img)
        g_losses.append(g_error/i)
        d_losses.append(d_error/i)
        print('epoch {}: g_loss: {:.4f} d_loss: {:.4f}'.format(epoch, g_error/i, d_error/i))

print('training finished')
torch.save(generator.state_dict(), 'mlat_generator.pth')

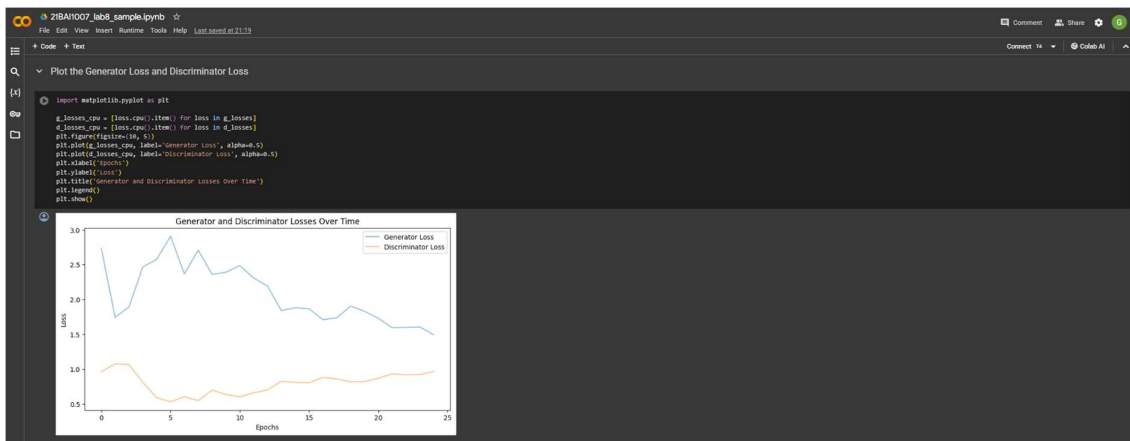
def to_image(tensor):
    """Converts a PyTorch tensor to a PIL image"""
    return to_pil_image(tensor)

import numpy as np
from matplotlib import pyplot as plt
imgs = [np.array(to_image(i)) for i in images]
images_minmax = (imgs[0], imgs[-1])

```

```
215A1007_lab8_sample.ipynb
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Epoch #: g_loss: 2.73811998 d_loss: 0.9043466
Epoch 1: g_loss: 1.74289369 d_loss: 0.8043466
Epoch 2: g_loss: 1.8287959 d_loss: 1.06447339
Epoch 3: g_loss: 2.4662785 d_loss: 0.8043466
Epoch 4: g_loss: 2.57938127 d_loss: 0.5859959
Epoch 5: g_loss: 2.59731021 d_loss: 0.5266569
Epoch 6: g_loss: 2.36623914 d_loss: 0.64219951
Epoch 7: g_loss: 2.59731021 d_loss: 0.5266569
Epoch 8: g_loss: 2.35316473 d_loss: 0.4985535
Epoch 9: g_loss: 2.39181123 d_loss: 0.5044226
Epoch 10: g_loss: 2.4563685 d_loss: 0.6882858
Epoch 11: g_loss: 2.39508618 d_loss: 0.50962399
Epoch 12: g_loss: 2.3532559 d_loss: 0.78854847
Epoch 13: g_loss: 1.83584169 d_loss: 0.4230866
Epoch 14: g_loss: 1.82883837 d_loss: 0.50629234
Epoch 15: g_loss: 1.85025379 d_loss: 0.48242454
Epoch 16: g_loss: 1.76507148 d_loss: 0.67824231
Epoch 17: g_loss: 1.73803378 d_loss: 0.48708084
Epoch 18: g_loss: 1.96385179 d_loss: 0.51626238
Epoch 19: g_loss: 1.43828822 d_loss: 0.8187879
Epoch 20: g_loss: 1.7284446 d_loss: 0.68030664
Epoch 21: g_loss: 1.59413558 d_loss: 0.51133583
Epoch 22: g_loss: 1.5577368 d_loss: 0.55455589
Epoch 23: g_loss: 1.4888214 d_loss: 0.52183828
Epoch 24: g_loss: 1.4888214 d_loss: 0.56038368
Training finished
```



Code and Output for Aim (ii)

```
21ba1007-cifar10-gan.pyb
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+ Code + Test
Vanilla GAN on CIFAR-10 Dataset
Goudham Krishna - 21BA1007

1 import torch
import torch.nn as nn
import torch.optim as optim
from torch.autograd.variable import Variable
from torchvision import transforms
from torchvision.datasets import CIFAR10
from torchvision.utils import make_grid
from torch.utils.data import DataLoader
import images

from torchvision.transforms.functional import to_pil_image

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2ba1007-cifar10-gan.pyb
File Edit View Insert Runtime Tools Help Last saved at 21:13
+ Code + Test
criterion = nn.L1Loss()

def noise(n, features=100):
    return variable(torch.randn(n, features)).to(device)

def make_noise(size):
    data = variable(torch.ones(size, 1))
    return data.to(device)

def make_real(size):
    data = variable(torch.zeros(size, 1))
    return data.to(device)

def train_discriminator(optimizer, real_data, fake_data):
    n = real_data.size(0)
    optimizer.zero_grad()
    prediction_real = discriminator(real_data)
    error_real = criterion(prediction_real, make_real(n))
    error_real.backward()

    prediction_fake = discriminator(fake_data)
    error_fake = criterion(prediction_fake, make_real(n))
    error_fake.backward()
    optimizer.step()

    return error_real + error_fake

def train_generator(optimizer, fake_data):
    n = fake_data.size(0)
    optimizer.zero_grad()

    prediction = discriminator(fake_data)
    error = criterion(prediction, make_real(n))
    error.backward()
    optimizer.step()

    return error

nuc_epochs = 30
k = 1
test_noise = noise(64)
```

```
2ba1007-cifar10-gan.pyb
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+ Code + Test
optimizer.step()

return error

nuc_epochs = 30
k = 1
test_noise = noise(64)

generator.train()
discriminator.train()
for epoch in range(nuc_epochs):
    g_error = 0.0
    d_error = 0.0
    for i, data in enumerate(trainloader):
        img, _ = data
        n = img.size(0)
        for j in range(1):
            Test_data = generator(noise(n)).detach()
            real_data = img.to(device)
            d_error += train_discriminator(d_optim, real_data, fake_data)
            fake_data = generator(noise(n))
            g_error += train_generator(g_optim, fake_data)

        img = generator(test_noise.cpu()).detach()
        img = make_grid(img)
        images.append(img)
        g_losses.append(g_error/i)
        d_losses.append(d_error/i)
        print('Epoch [%d] d_loss: %.4f g_loss: %.4f' % (epoch, g_error/i, d_error/i))

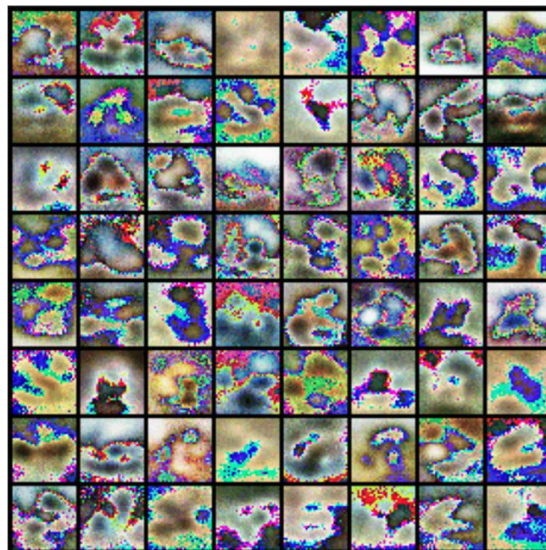
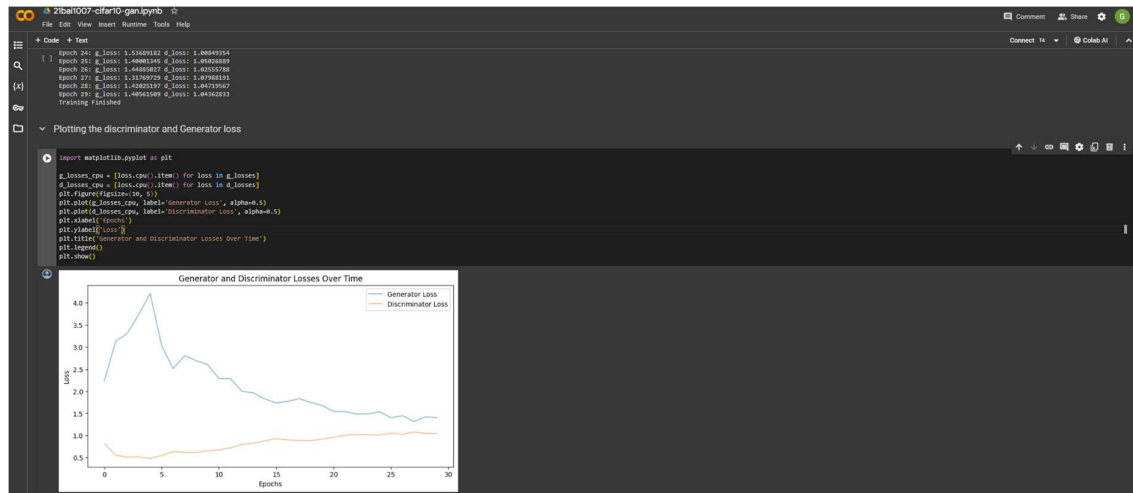
print('Training finished')
torch.save(generator.state_dict(), 'misit_generator.pth')

def to_image(tensor):
    """Converts a PyTorch tensor to a PIL image."""
    return to_pil_image(tensor)

import numpy as np
from matplotlib import pyplot as plt
img = [to_image(img) for i, img in images]
imagesio.imshow('progress.gif', img)
```

```
2ba1007-cifar10-gan.pyb
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+ Code + Test
img = to_image(img)
imagesio.imshow('progress.gif', img)

Epoch #: g_loss: 2.23462745 d_loss: 0.82479874
Epoch 1: g_loss: 2.13480154 d_loss: 0.52245654
Epoch 2: g_loss: 2.38779939 d_loss: 0.5122852
Epoch 3: g_loss: 2.7224966 d_loss: 0.52066226
Epoch 4: g_loss: 2.22480553 d_loss: 0.47972389
Epoch 5: g_loss: 2.40382546 d_loss: 0.55872351
Epoch 6: g_loss: 2.38914526 d_loss: 0.63532798
Epoch 7: g_loss: 2.38933828 d_loss: 0.62433158
Epoch 8: g_loss: 2.69118155 d_loss: 0.61798481
Epoch 9: g_loss: 2.49524489 d_loss: 0.52120766
Epoch 10: g_loss: 2.2683758 d_loss: 0.67467679
Epoch 11: g_loss: 2.28377876 d_loss: 0.74302525
Epoch 12: g_loss: 1.99444444 d_loss: 0.77918825
Epoch 13: g_loss: 1.3631556 d_loss: 0.85458439
Epoch 14: g_loss: 1.42608623 d_loss: 0.82737793
Epoch 15: g_loss: 1.74615219 d_loss: 0.95456683
Epoch 16: g_loss: 1.77444279 d_loss: 0.88228356
Epoch 17: g_loss: 1.43143216 d_loss: 0.86465656
Epoch 18: g_loss: 1.74755453 d_loss: 0.88514179
Epoch 19: g_loss: 1.47677153 d_loss: 0.94505664
Epoch 20: g_loss: 1.54414312 d_loss: 0.92837782
Epoch 21: g_loss: 1.54642912 d_loss: 1.06526044
Epoch 22: g_loss: 1.48379228 d_loss: 1.02389742
Epoch 23: g_loss: 1.46837769 d_loss: 1.04022579
Epoch 24: g_loss: 1.57689182 d_loss: 1.08849354
Epoch 25: g_loss: 1.40881346 d_loss: 1.05035889
Epoch 26: g_loss: 1.44855627 d_loss: 1.02055788
Epoch 27: g_loss: 1.21387572 d_loss: 1.07010181
Epoch 28: g_loss: 1.42855197 d_loss: 1.04775567
Epoch 29: g_loss: 1.49011997 d_loss: 1.04062833
Training finished
```



Results

Successfully generated images of MNIST Handwritten digits dataset with a generator loss of 1.49 and discriminator loss of 0.96. The generated image is clear and distinguishable as digits.

For the CIFAR-10 image dataset, Vanilla GAN did not turn out to be effective since only dense layers are being used to generate and discriminate images. The generated image after 30 epochs is pixelated and cannot be recognized as specific images. A DCGAN using convolution layers will be more effective for three dimensional and complex image datasets like CIFAR.