CGANs

April 24, 2024

[2]:
```
pip install torch
```

```
Defaulting to user installation because normal site-packages is not writeable
Collecting torch
  Downloading torch-2.2.2-cp311-cp311-manylinux1_x86_64.whl.metadata (25 kB)
Requirement already satisfied: filelock in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch) (3.13.1)
Requirement already satisfied: typing-extensions>=4.8.0 in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch) (4.9.0)
Requirement already satisfied: sympy in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch) (1.12)
Requirement already satisfied: networkx in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch) (3.1)
Requirement already satisfied: jinja2 in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch) (3.1.3)
Requirement already satisfied: fsspec in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from torch)
(2023.10.0)
Collecting nvidia-cuda-nvrtc-cu12==12.1.105 (from torch)
  Downloading nvidia_cuda_nvrtc_cu12-12.1.105-py3-none-
manylinux1_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cuda-runtime-cu12==12.1.105 (from torch)
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manylinux1_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cuda-cupti-cu12==12.1.105 (from torch)
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(1.6 kB)
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manylinux1_x86_64.whl.metadata (1.5 kB)
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Collecting nvidia-curand-cu12==10.3.2.106 (from torch)
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manylinux1_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cusolver-cu12==11.4.5.107 (from torch)
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Collecting nvidia-cusparse-cu12==12.1.0.106 (from torch)
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(1.8 kB)
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(1.7 kB)
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triton-2.2.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata
(1.4 kB)
Collecting nvidia-nvjitlink-cu12 (from nvidia-cusolver-cu12==11.4.5.107->torch)
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(2.1.3)
Requirement already satisfied: mpmath>=0.19 in
/apps/cent7/anaconda/2024.02/lib/python3.11/site-packages (from sympy->torch)
(1.3.0)
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manylinux2014_x86_64.whl (21.1 MB)
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51.7 MB/s eta 0:00:00:00:0100:01
Installing collected packages: triton, nvidia-nvtx-cu12, nvidia-nvjitlink-
cu12, nvidia-nccl-cu12, nvidia-curand-cu12, nvidia-cufft-cu12, nvidia-cuda-
runtime-cu12, nvidia-cuda-nvrtc-cu12, nvidia-cuda-cupti-cu12, nvidia-cublas-
cu12, nvidia-cusparse-cu12, nvidia-cudnn-cu12, nvidia-cusolver-cu12, torch
  WARNING: The scripts convert-caffe2-to-onnx, convert-onnx-to-caffe2 and
torchrun are installed in '/home/mrameshk/.local/bin' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this
warning, use --no-warn-script-location.
Successfully installed nvidia-cublas-cu12-12.1.3.1 nvidia-cuda-cupti-
cu12-12.1.105 nvidia-cuda-nvrtc-cu12-12.1.105 nvidia-cuda-runtime-cu12-12.1.105
nvidia-cudnn-cu12-8.9.2.26 nvidia-cufft-cu12-11.0.2.54 nvidia-curand-
```

```
cu12-10.3.2.106 nvidia-cusolver-cu12-11.4.5.107 nvidia-cusparse-cu12-12.1.0.106
nvidia-nccl-cu12-2.19.3 nvidia-nvjitlink-cu12-12.4.127 nvidia-nvtx-cu12-12.1.105
torch-2.2.2 triton-2.2.0
Note: you may need to restart the kernel to use updated packages.
```

[1]:
```python
import torch
import torch.nn as nn
import torch.optim as optim
from torchvision import datasets, transforms
from torch.utils.data import DataLoader
from torchvision.utils import save_image
import numpy as np
```

[2]:
```python
# Set device
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

[3]:
```python
# Hyperparameters
batch_size = 64
latent_dim = 100
num_classes = 10
lr = 0.0002
epochs = 50
```

[4]:
```python
# Generator network
class Generator(nn.Module):
    def __init__(self):
        super(Generator, self).__init__()
        self.label_emb = nn.Embedding(num_classes, num_classes)
        self.model = nn.Sequential(
            nn.Linear(latent_dim + num_classes, 128),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(128, 256),
            nn.BatchNorm1d(256),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(256, 512),
            nn.BatchNorm1d(512),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(512, 1024),
            nn.BatchNorm1d(1024),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(1024, 32 * 32 * 3),
            nn.Tanh()
        )

    def forward(self, noise, labels):
        gen_input = torch.cat((self.label_emb(labels), noise), -1)
        img = self.model(gen_input)
```

```
        img = img.view(img.size(0), 3, 32, 32)
        return img
```

[5]:
```
# Discriminator network
class Discriminator(nn.Module):
    def __init__(self):
        super(Discriminator, self).__init__()
        self.label_emb = nn.Embedding(num_classes, num_classes)
        self.model = nn.Sequential(
            nn.Linear(num_classes + 32 * 32 * 3, 512),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(512, 256),
            nn.LeakyReLU(0.2, inplace=True),
            nn.Linear(256, 1),
            nn.Sigmoid()
        )

    def forward(self, img, labels):
        d_in = img.view(img.size(0), -1)
        dis_input = torch.cat((d_in, self.label_emb(labels)), -1)
        validity = self.model(dis_input)
        return validity
```

[6]:
```
# Initialize networks
generator = Generator().to(device)
discriminator = Discriminator().to(device)
```

[7]:
```
# Loss function
adversarial_loss = nn.BCELoss()
```

[8]:
```
# Optimizers
optimizer_G = optim.Adam(generator.parameters(), lr=lr, betas=(0.5, 0.999))
optimizer_D = optim.Adam(discriminator.parameters(), lr=lr, betas=(0.5, 0.999))
```

[9]:
```
# Dataset and DataLoader
transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))
])
dataset = datasets.CIFAR10(root='./data', train=True, download=True,␣
 ↪transform=transform)
dataloader = DataLoader(dataset, batch_size=batch_size, shuffle=True)
```

```
Files already downloaded and verified
```

[14]:
```
# Training loop
for epoch in range(epochs):
```

```
    for i, (imgs, labels) in enumerate(dataloader):
        # Adversarial ground truths
        valid = torch.ones(imgs.size(0), 1, device=device)
        fake = torch.zeros(imgs.size(0), 1, device=device)

        # Configure input
        real_imgs = imgs.to(device)
        labels = labels.to(device)
        z = torch.randn(imgs.size(0), latent_dim, device=device)

        # Generate a batch of images
        gen_imgs = generator(z, labels)

        # Train Discriminator
        optimizer_D.zero_grad()
        real_loss = adversarial_loss(discriminator(real_imgs, labels), valid)
        fake_loss = adversarial_loss(discriminator(gen_imgs.detach(), labels),␣
↪fake)
        d_loss = (real_loss + fake_loss) / 2
        d_loss.backward()
        optimizer_D.step()

        # Train Generator
        optimizer_G.zero_grad()
        g_loss = adversarial_loss(discriminator(gen_imgs, labels), valid)
        g_loss.backward()
        optimizer_G.step()

        # Print progress
        if i % 100 == 0:
            print(
                "[Epoch %d/%d] [Batch %d/%d] [D loss: %f] [G loss: %f]"
                % (epoch, epochs, i, len(dataloader), d_loss.item(), g_loss.
↪item())
            )
```

```
[Epoch 0/50] [Batch 0/782] [D loss: 0.686213] [G loss: 0.773332]
[Epoch 0/50] [Batch 100/782] [D loss: 0.550754] [G loss: 2.193638]
[Epoch 0/50] [Batch 200/782] [D loss: 0.526967] [G loss: 2.284229]
[Epoch 0/50] [Batch 300/782] [D loss: 0.571764] [G loss: 2.181199]
[Epoch 0/50] [Batch 400/782] [D loss: 0.494528] [G loss: 1.337056]
[Epoch 0/50] [Batch 500/782] [D loss: 0.530762] [G loss: 1.658349]
[Epoch 0/50] [Batch 600/782] [D loss: 0.645877] [G loss: 1.611205]
[Epoch 0/50] [Batch 700/782] [D loss: 0.577461] [G loss: 1.286520]
[Epoch 1/50] [Batch 0/782] [D loss: 0.614734] [G loss: 1.498957]
[Epoch 1/50] [Batch 100/782] [D loss: 0.571891] [G loss: 1.526343]
[Epoch 1/50] [Batch 200/782] [D loss: 0.628477] [G loss: 1.600659]
```

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[Epoch 1/50] [Batch 400/782] [D loss: 0.642344] [G loss: 1.426045]
[Epoch 1/50] [Batch 500/782] [D loss: 0.574255] [G loss: 1.362322]
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[Epoch 1/50] [Batch 700/782] [D loss: 0.660527] [G loss: 1.321881]
[Epoch 2/50] [Batch 0/782] [D loss: 0.596594] [G loss: 1.264020]
[Epoch 2/50] [Batch 100/782] [D loss: 0.556974] [G loss: 1.233069]
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[Epoch 7/50] [Batch 100/782] [D loss: 0.686512] [G loss: 0.886571]
[Epoch 7/50] [Batch 200/782] [D loss: 0.691185] [G loss: 0.871325]
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[Epoch 42/50] [Batch 300/782] [D loss: 0.682068] [G loss: 0.776558]
[Epoch 42/50] [Batch 400/782] [D loss: 0.681742] [G loss: 0.822610]
[Epoch 42/50] [Batch 500/782] [D loss: 0.698116] [G loss: 0.842485]
[Epoch 42/50] [Batch 600/782] [D loss: 0.663506] [G loss: 0.821735]
[Epoch 42/50] [Batch 700/782] [D loss: 0.656580] [G loss: 0.802563]
[Epoch 43/50] [Batch 0/782] [D loss: 0.704543] [G loss: 0.783055]
[Epoch 43/50] [Batch 100/782] [D loss: 0.707649] [G loss: 0.837421]
[Epoch 43/50] [Batch 200/782] [D loss: 0.671511] [G loss: 0.859313]
```

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[Epoch 43/50] [Batch 300/782] [D loss: 0.672527] [G loss: 0.808686]
[Epoch 43/50] [Batch 400/782] [D loss: 0.671589] [G loss: 0.817296]
[Epoch 43/50] [Batch 500/782] [D loss: 0.682158] [G loss: 0.888191]
[Epoch 43/50] [Batch 600/782] [D loss: 0.689762] [G loss: 0.789384]
[Epoch 43/50] [Batch 700/782] [D loss: 0.642838] [G loss: 0.829041]
[Epoch 44/50] [Batch 0/782] [D loss: 0.750337] [G loss: 0.853795]
[Epoch 44/50] [Batch 100/782] [D loss: 0.681024] [G loss: 0.843411]
[Epoch 44/50] [Batch 200/782] [D loss: 0.639612] [G loss: 0.805444]
[Epoch 44/50] [Batch 300/782] [D loss: 0.659595] [G loss: 0.836054]
[Epoch 44/50] [Batch 400/782] [D loss: 0.673118] [G loss: 0.938304]
[Epoch 44/50] [Batch 500/782] [D loss: 0.684726] [G loss: 0.893591]
[Epoch 44/50] [Batch 600/782] [D loss: 0.697723] [G loss: 0.833841]
[Epoch 44/50] [Batch 700/782] [D loss: 0.649231] [G loss: 0.857690]
[Epoch 45/50] [Batch 0/782] [D loss: 0.675245] [G loss: 0.795590]
[Epoch 45/50] [Batch 100/782] [D loss: 0.670245] [G loss: 0.846281]
[Epoch 45/50] [Batch 200/782] [D loss: 0.653407] [G loss: 0.847090]
[Epoch 45/50] [Batch 300/782] [D loss: 0.681311] [G loss: 0.826101]
[Epoch 45/50] [Batch 400/782] [D loss: 0.689150] [G loss: 0.862625]
[Epoch 45/50] [Batch 500/782] [D loss: 0.674335] [G loss: 0.856791]
[Epoch 45/50] [Batch 600/782] [D loss: 0.689264] [G loss: 0.813332]
[Epoch 45/50] [Batch 700/782] [D loss: 0.657800] [G loss: 0.868573]
[Epoch 46/50] [Batch 0/782] [D loss: 0.722746] [G loss: 0.817835]
[Epoch 46/50] [Batch 100/782] [D loss: 0.679022] [G loss: 0.774802]
[Epoch 46/50] [Batch 200/782] [D loss: 0.698192] [G loss: 0.813098]
[Epoch 46/50] [Batch 300/782] [D loss: 0.667976] [G loss: 0.775944]
[Epoch 46/50] [Batch 400/782] [D loss: 0.680952] [G loss: 0.812754]
[Epoch 46/50] [Batch 500/782] [D loss: 0.683400] [G loss: 0.844556]
[Epoch 46/50] [Batch 600/782] [D loss: 0.679073] [G loss: 0.839314]
[Epoch 46/50] [Batch 700/782] [D loss: 0.658025] [G loss: 0.826078]
[Epoch 47/50] [Batch 0/782] [D loss: 0.628748] [G loss: 0.926810]
[Epoch 47/50] [Batch 100/782] [D loss: 0.646956] [G loss: 0.942500]
[Epoch 47/50] [Batch 200/782] [D loss: 0.646750] [G loss: 0.847871]
[Epoch 47/50] [Batch 300/782] [D loss: 0.700027] [G loss: 0.816902]
[Epoch 47/50] [Batch 400/782] [D loss: 0.682526] [G loss: 0.875486]
[Epoch 47/50] [Batch 500/782] [D loss: 0.661803] [G loss: 0.866508]
[Epoch 47/50] [Batch 600/782] [D loss: 0.691725] [G loss: 0.938351]
[Epoch 47/50] [Batch 700/782] [D loss: 0.645107] [G loss: 0.927472]
[Epoch 48/50] [Batch 0/782] [D loss: 0.630315] [G loss: 0.978535]
[Epoch 48/50] [Batch 100/782] [D loss: 0.653762] [G loss: 0.876106]
[Epoch 48/50] [Batch 200/782] [D loss: 0.665909] [G loss: 0.914678]
[Epoch 48/50] [Batch 300/782] [D loss: 0.665379] [G loss: 0.850934]
[Epoch 48/50] [Batch 400/782] [D loss: 0.706133] [G loss: 0.858857]
[Epoch 48/50] [Batch 500/782] [D loss: 0.630533] [G loss: 0.972926]
[Epoch 48/50] [Batch 600/782] [D loss: 0.672435] [G loss: 0.822091]
[Epoch 48/50] [Batch 700/782] [D loss: 0.685214] [G loss: 0.881342]
[Epoch 49/50] [Batch 0/782] [D loss: 0.674219] [G loss: 0.950218]
[Epoch 49/50] [Batch 100/782] [D loss: 0.670198] [G loss: 0.902312]
[Epoch 49/50] [Batch 200/782] [D loss: 0.672085] [G loss: 0.884248]
```

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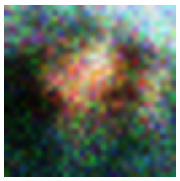
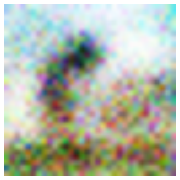
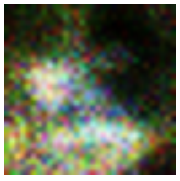
[Epoch 49/50] [Batch 300/782] [D loss: 0.668259] [G loss: 1.122321]
[Epoch 49/50] [Batch 400/782] [D loss: 0.650512] [G loss: 0.866942]
[Epoch 49/50] [Batch 500/782] [D loss: 0.585001] [G loss: 0.984846]
[Epoch 49/50] [Batch 600/782] [D loss: 0.632986] [G loss: 0.986673]
[Epoch 49/50] [Batch 700/782] [D loss: 0.649496] [G loss: 0.942724]
```

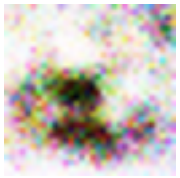
[37]:
```python
from torchvision.utils import save_image
from PIL import Image as PILImage

def generate_and_display_images(generator, label, num_images=5,␣
 ↪resize_factor=2):
    z = torch.randn(num_images, latent_dim, device=device)
    labels = torch.full((num_images,), label, dtype=torch.long, device=device)
    gen_imgs = generator(z, labels)
    for i in range(num_images):
        save_image(gen_imgs[i], f"images/{label}_{i}.png", normalize=True)
        img_path = f"images/{label}_{i}.png"
        img = PILImage.open(img_path)
        img = img.resize((img.width * resize_factor, img.height *␣
 ↪resize_factor))
        display(img)
```

[43]:
```python
# Generate and display images of dogs (class label = 3 for CIFAR-10)
#label = 5 is dog
generate_and_display_images(generator, label=5, num_images=5)
```









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