MNIST-DCGAN-v1.0

February 13, 2022

1 Deep Convolutional GAN - MNIST Dataset

In this notebook we are going to implement a little more complicated GAN, a Deep Convolutional one. like previous notebooks we will use MNIST dataset and PyTorch as deep learning framework.

Deep Convolutional GAN was developed in 2015 for the first time and the reference paper of it can be accessed from here.

Architecture of the network is like this:

Generator: 1. Noise vector: (64) 2. Block1: [ConvTranspose(64, 256), Filter: 3, Stride: 2] -> BatchNormalization(256) -> ReLU 3. Block2: [ConvTranspose(256, 128), Filter: 4, Stride: 1] -> BatchNormalization(128) -> ReLU 4. Block3: [ConvTranspose(128, 64), Filter: 3, Stride: 2] -> BatchNormalization(128) -> ReLU 5. Block4: [ConvTranspose(64, 1), Filter: 4, Stride: 2] -> Tanh

Discriminator: 1. Image: (28, 28, 1) 2. Block1: [Conv2D(1, 16), Filter: 4, Stride: 2] -> BatchNormalization(16) -> LeakyReLU(0.2) 3. Block2: [Conv2D(16, 32), Filter: 4, Stride: 2] -> BatchNormalization(32) -> LeakyReLU(0.2) 4. Block3: [Conv2D(32, 1), Filter: 4, Stride: 2]

Features of this network are listed here: - No pooling layer - batch normalization in generator and discriminator - No Fully connected layer - ReLU activation in generator for all layers except the last layer, which is Tanh - LeakyReLU activation in discriminator for all layers except the last layer which don't need activation.

You might be wondering why we are using Transposed Convolution in Generator. Transposed Convolutions are also known as DeConvolutions. This means that they are operating as an upsampling with a filter. We are using Transposed Convolution becuase we want to make our noise which is a vector to an image which is a 3D Tensor.

[ ]:
```
import torch
from torch import nn
from tqdm.auto import tqdm
from torchvision import transforms
from torchvision.datasets import MNIST # Training dataset
from torchvision.utils import make_grid
from torch.utils.data import DataLoader
import matplotlib.pyplot as plt

def show_tensor_images(image_tensor, num_images=25, size=(1, 28, 28)):
    '''
    Function for visualizing images: Given a tensor of images, number of␣
↪images, and
    size per image, plots and prints the images in a uniform grid.
    '''
    image_unflat = image_tensor.detach().cpu().view(-1, *size)
    image_grid = make_grid(image_unflat[:num_images], nrow=5)
    plt.imshow(image_grid.permute(1, 2, 0).squeeze())
    plt.show()

def generate_noise(n_samples, noise_dim, device = 'cpu'):
    '''
    A Helper function for creating random noise vectors with the dimension of:␣
↪(n_samples, noise_dim)
    random numbers are from normal distribution
    Input ->
        n_samples: number of samples to generate (row)
        noise_dim: dimension of nouse vector (column)
        device: device type
    '''
    return torch.randn(n_samples, noise_dim, device=device)
```

1.1 Generator

```
[ ]: class Generator(nn.Module):
    '''
    This class is for generator.
    Inputs ->
        noise_dim: dimension of noise vector.
        image_channel: number of channels in images,(Since MNIST is black and␣
↪white images have 1 channel.)
        hidden_dim: inner dimension of networks.
    '''
    def __init__(self, noise_dim=10, image_channel=1, hidden_dim=64):
        super(Generator, self).__init__()
        self.noise_dim = noise_dim
        self.block1 = nn.Sequential(
            nn.ConvTranspose2d(noise_dim, hidden_dim * 4, kernel_size=3,␣
↪stride=2),
            nn.BatchNorm2d(hidden_dim * 4),
            nn.ReLU()
        )
        self.block2 = nn.Sequential(
            nn.ConvTranspose2d(hidden_dim * 4, hidden_dim * 2, kernel_size=4,␣
↪stride=1),
            nn.BatchNorm2d(hidden_dim * 2),
            nn.ReLU()
        )
        self.block3 = nn.Sequential(
            nn.ConvTranspose2d(hidden_dim * 2, hidden_dim, kernel_size=3,␣
↪stride=2),
            nn.BatchNorm2d(hidden_dim),
            nn.ReLU()
        )
        self.block4 = nn.Sequential(
            nn.ConvTranspose2d(hidden_dim, image_channel, kernel_size=4,␣
↪stride=2),
            nn.Tanh()
        )

    def unsqueeze_noise(self, noise):
        '''
        A helper function for reshaping the noise vector. reshaping noise␣
↪vector to (number of samples, noise_dim, 1, 1)
        Input ->
            a noise tensor with the shape of (number of samples, noise_dim)
        Output ->
            a copy of noise with shape of (number of samples, noise_dim, 1, 1)
        '''
        return noise.view(len(noise), self.noise_dim, 1, 1)

    def forward(self, noise):
        '''
        forward pass of generator.
        Input ->
            noise: noise tensor with shape of (number of samples, noise_dim)
        Output ->
            generated image
        '''
        out = self.unsqueeze_noise(noise)
        out = self.block1(out)
        out = self.block2(out)
        out = self.block3(out)
        out = self.block4(out)
        return out
```

1.2 Discriminator

[ ]:
```
class Discriminator(nn.Module):
    '''
    This class is for Dsicriminator
    Input ->
        image_channel: number of channels in images,(Since MNIST is black and␣
↪white images have 1 channel.)
        hidden_dim: inner dimension of networks.
    '''
    def __init__(self, image_channel=1, hidden_dim=16):
        super(Discriminator, self).__init__()
        self.block1 = nn.Sequential(
            nn.Conv2d(image_channel, hidden_dim, kernel_size=4, stride=2),
            nn.BatchNorm2d(hidden_dim),
            nn.LeakyReLU(.2)
        )
        self.block2 = nn.Sequential(
            nn.Conv2d(hidden_dim, hidden_dim * 2, kernel_size=4, stride=2),
            nn.BatchNorm2d(hidden_dim * 2),
            nn.LeakyReLU(.2)
        )
        self.block3 = nn.Sequential(
            nn.Conv2d(hidden_dim * 2, 1, kernel_size=4, stride=2)
        )
    def forward(self, image):
        '''
        Forward pass of discriminator
        Input ->
            image: flattened image tensor with dimension of (image_dim)
        Output ->
            returns a 1 dimension tensor representing whtether input image is␣
↪generated or original.
        '''
        out = self.block1(image)
        out = self.block2(out)
        out = self.block3(out)
        return out.view(len(out), -1)
```

1.3 Training

Like previous networks, we have some hyperparameters to address before beginning the training phase. you can see some of them here:

- Criterion: the loss function we want to use for our network
- n_epochs: number of epochs we want to train our network
- noise_dim: the dimension of noise vector
- display_step: in what steps we want to see a sample from generator
- batch_size: the size of our batch i.e. number of images to be passed to processod in forward and backward pass.
- lr: learning rate
- beta_1, beta_2: hyperparameters for momentum
- device: device type

[ ]:
```
criterion = nn.BCEWithLogitsLoss()
noise_dim = 64
display_step = 500
```

```
batch_size = 128
lr = .0002
beta_1 = .5
beta_2 = .999
device = 'cuda'

transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((.5,), (.5)),
])

dataloader = DataLoader(
    MNIST('./data', download=True, transform=transform),
    batch_size=batch_size, shuffle=True
)
```

[ ]:
```
gen = Generator(noise_dim).to(device)
gen_opt = torch.optim.Adam(gen.parameters(), lr=lr, betas=(beta_1, beta_2))
disc = Discriminator().to(device)
disc_opt = torch.optim.Adam(disc.parameters(), lr=lr, betas=(beta_1, beta_2))
```

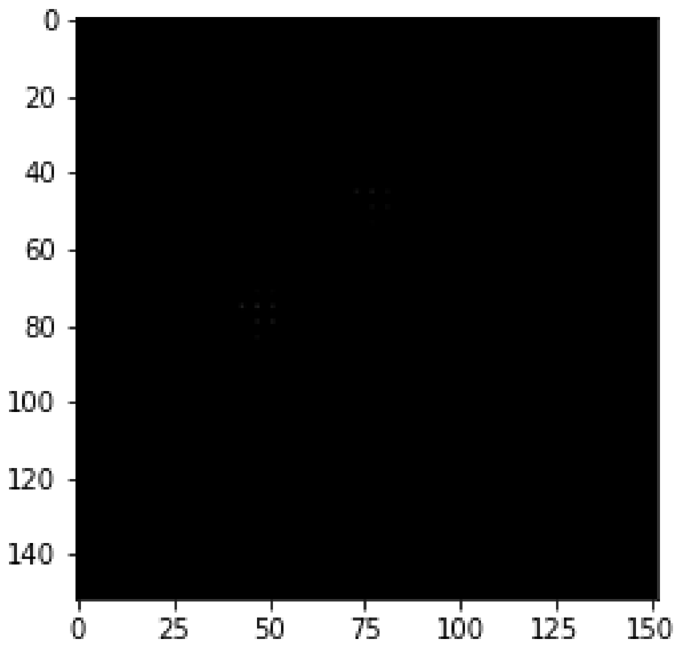
Initializing weights to the normal distribution with mean of 0 and standard deviation of 0.02

[ ]:
```
def weights_init(m):
    if isinstance(m, nn.Conv2d) or isinstance(m, nn.ConvTranspose2d):
        torch.nn.init.normal_(m.weight, 0.0, 0.02)
    if isinstance(m, nn.BatchNorm2d):
        torch.nn.init.normal_(m.weight, 0.0, 0.02)
        torch.nn.init.constant_(m.bias, 0)
gen = gen.apply(weights_init)
disc = disc.apply(weights_init)
```

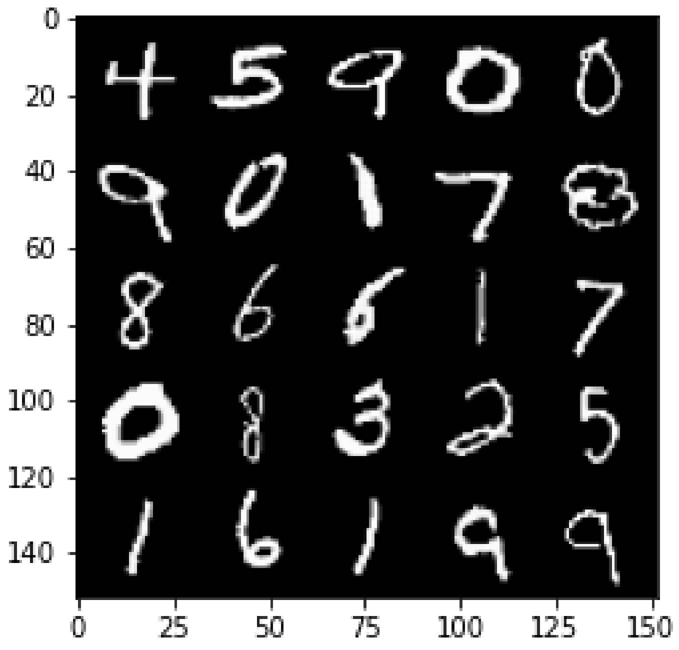
[ ]:
```
n_epochs = 50
cur_step = 0
mean_generator_loss = 0
mean_discriminator_loss = 0
for epoch in range(n_epochs):
    # Dataloader returns the batches
    for original, _ in tqdm(dataloader):
        cur_batch_size = len(original)
        original = original.to(device)

        ## Update discriminator ##
        disc_opt.zero_grad()
        generated_noise = generate_noise(cur_batch_size, noise_dim,␣
 ↪device=device)
        generated = gen(generated_noise)
        disc_generated_pred = disc(generated.detach())
        disc_generated_loss = criterion(disc_generated_pred, torch.
↪zeros_like(disc_generated_pred))
        disc_original_pred = disc(original)
        disc_original_loss = criterion(disc_original_pred, torch.
↪ones_like(disc_original_pred))
        disc_loss = (disc_generated_loss + disc_original_loss) / 2

        # Keep track of the average discriminator loss
        mean_discriminator_loss += disc_loss.item() / display_step
        # Update gradients
        disc_loss.backward(retain_graph=True)
        # Update optimizer
        disc_opt.step()

        ## Update generator ##
        gen_opt.zero_grad()
        generated_noise_2 = generate_noise(cur_batch_size, noise_dim,␣
↪device=device)
        generated_2 = gen(generated_noise_2)
        disc_generated_pred = disc(generated_2)
        gen_loss = criterion(disc_generated_pred, torch.
↪ones_like(disc_generated_pred))
        gen_loss.backward()
        gen_opt.step()

        # Keep track of the average generator loss
        mean_generator_loss += gen_loss.item() / display_step

        ## Visualization code ##
        if cur_step % display_step == 0 and cur_step > 0:
            print(f"Epoch {epoch}, Step {cur_step} -> Generator loss:␣
↪{mean_generator_loss}, discriminator loss: {mean_discriminator_loss}")
            show_tensor_images(generated)
            show_tensor_images(original)
            mean_generator_loss = 0
            mean_discriminator_loss = 0
        cur_step += 1
```

```
100%|     | 469/469 [00:44<00:00, 10.47it/s]
  6%|         | 30/469 [00:02<00:40, 10.89it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

```
Epoch 1, Step 500 -> Generator loss: 1.023333115935326, discriminator loss:
0.4706256099641326
```



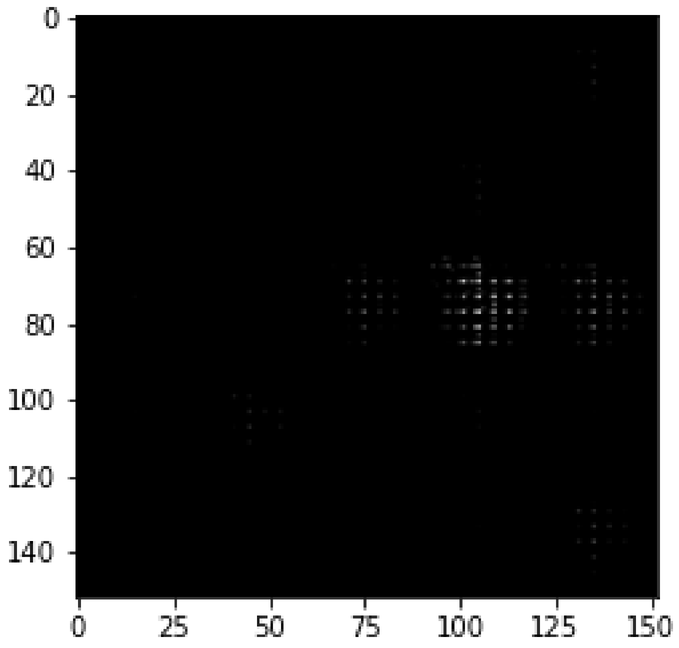
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



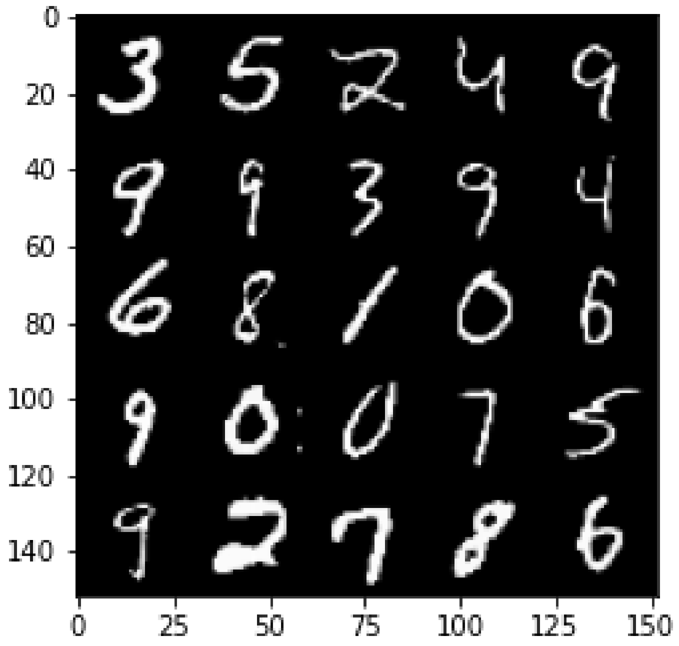
```
100%|      | 469/469 [00:44<00:00, 10.56it/s]
```

```
 13%|         | 62/469 [00:05<00:38, 10.49it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

```
Epoch 2, Step 1000 -> Generator loss: 2.667801036834716, discriminator loss:
0.09682307601720105
```

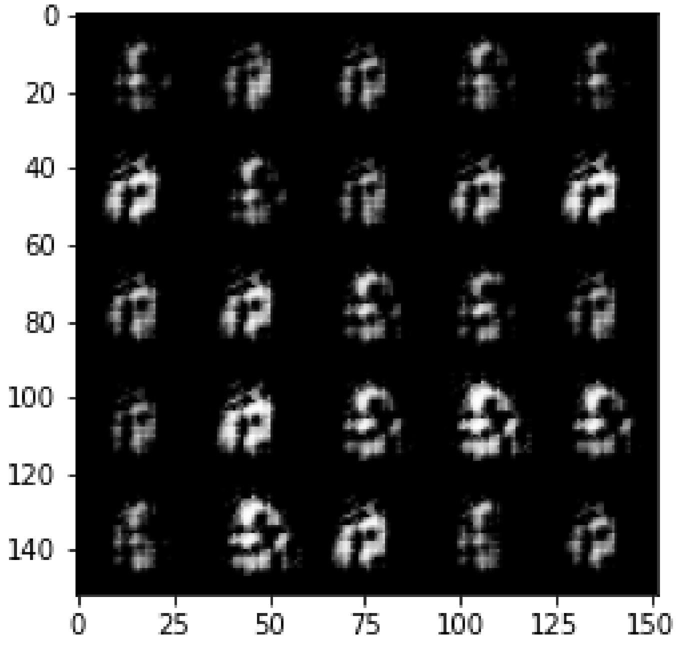


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

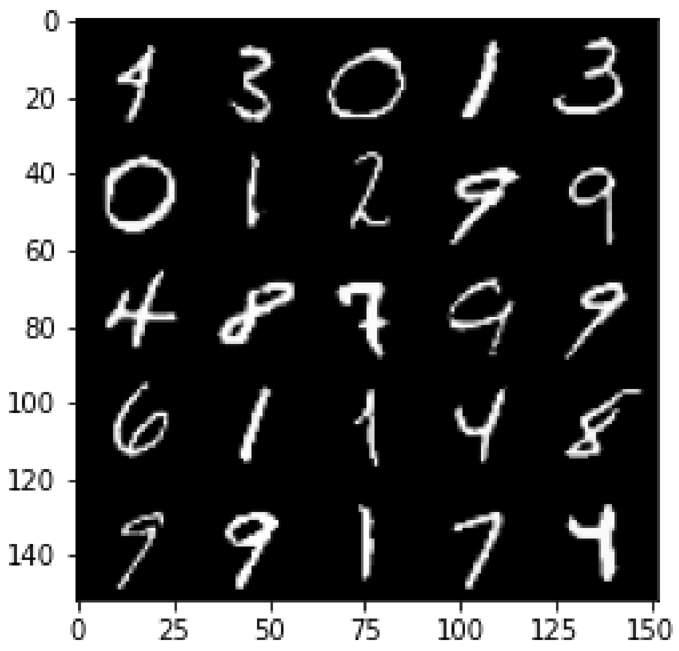


```
100%|      | 469/469 [00:45<00:00, 10.29it/s]
 20%|         | 93/469 [00:09<00:36, 10.39it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

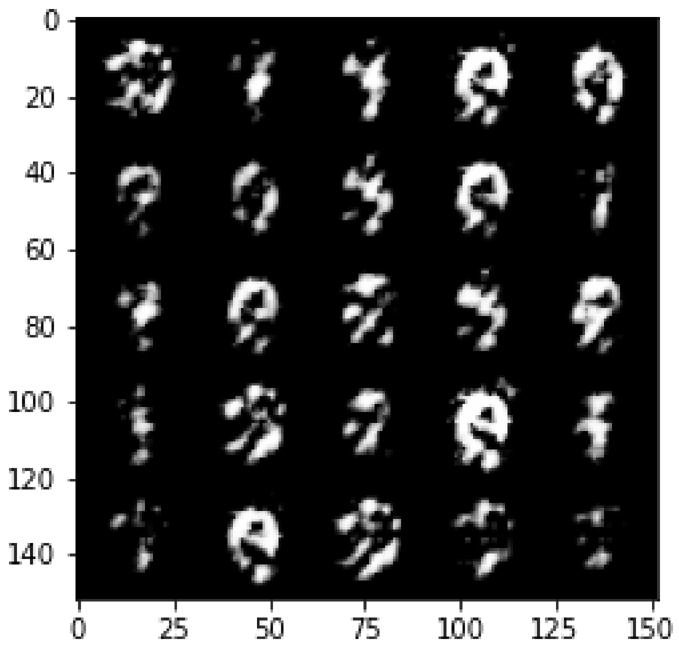
```
Epoch 3, Step 1500 -> Generator loss: 2.880452744394541, discriminator loss:
0.1942758893556892
```



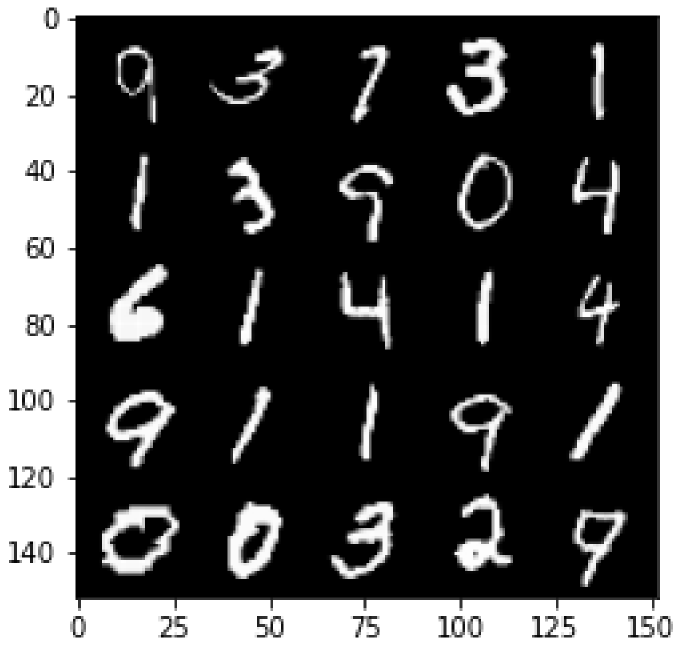
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:46<00:00, 10.05it/s]
 26%|         | 124/469 [00:12<00:36,  9.46it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 4, Step 2000 -> Generator loss: 1.7510962737128144, discriminator loss:
0.3977774573415514
```

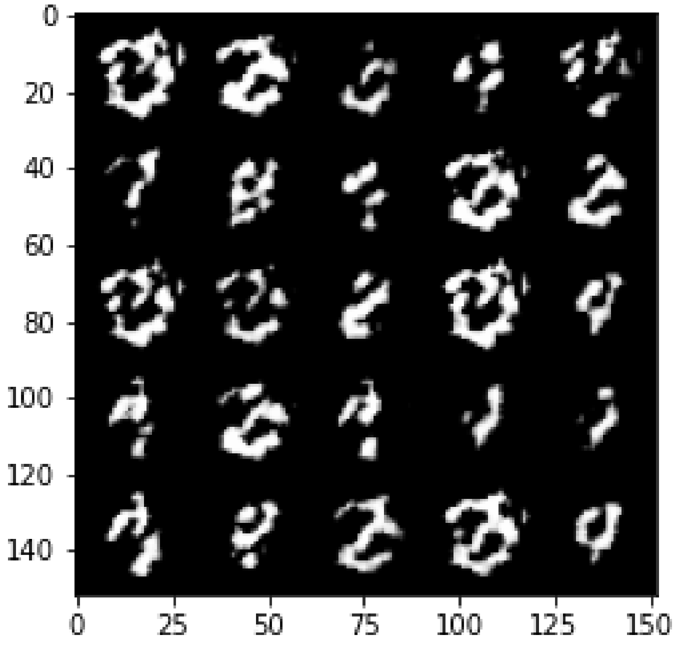


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

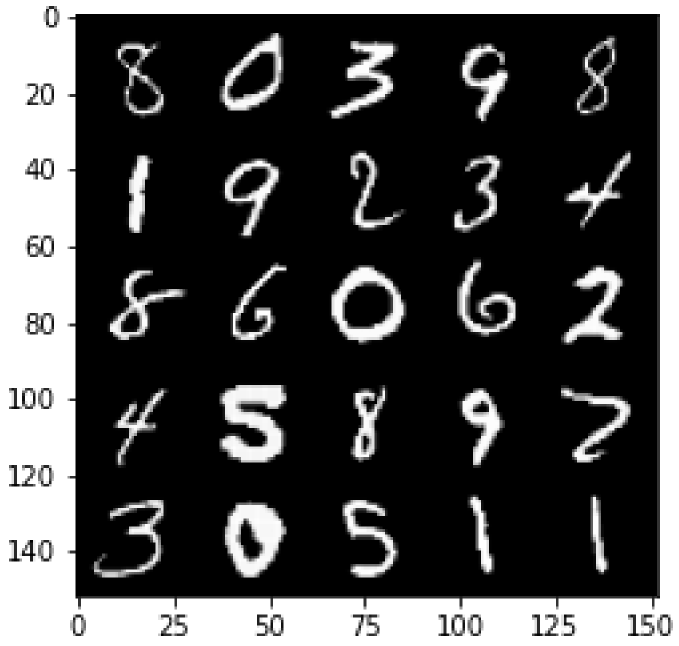


```
100%|      | 469/469 [00:48<00:00,  9.73it/s]
```

```
 33%|        | 155/469 [00:15<00:32,  9.70it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 5, Step 2500 -> Generator loss: 1.42668802511692, discriminator loss:
0.43327729159593564
```

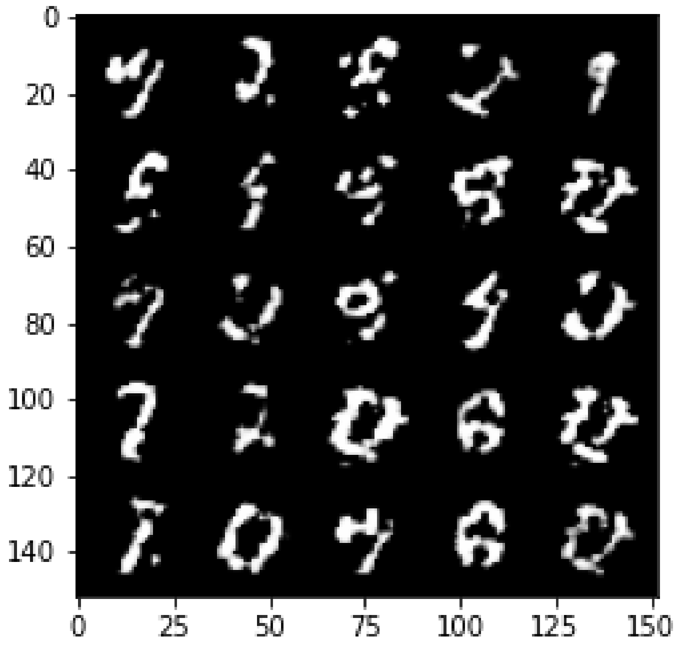


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

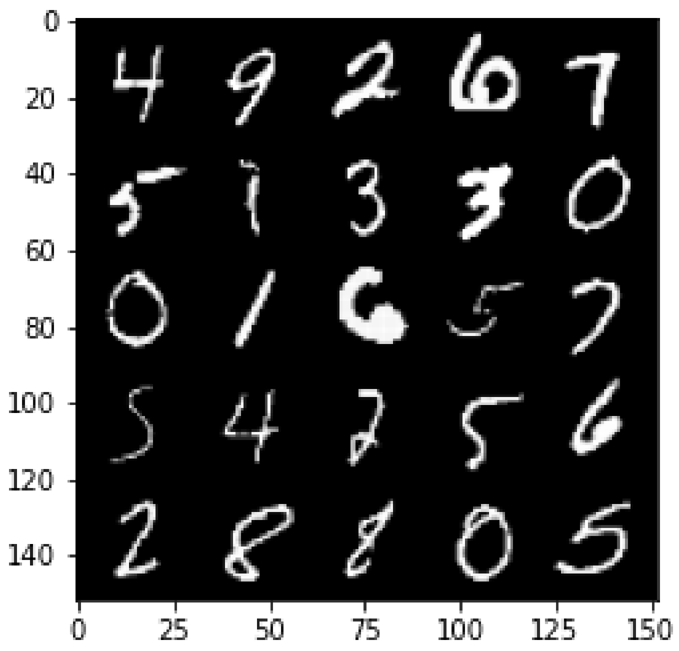


```
100%|      | 469/469 [00:48<00:00,  9.67it/s]
 40%|        | 186/469 [00:19<00:30,  9.28it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

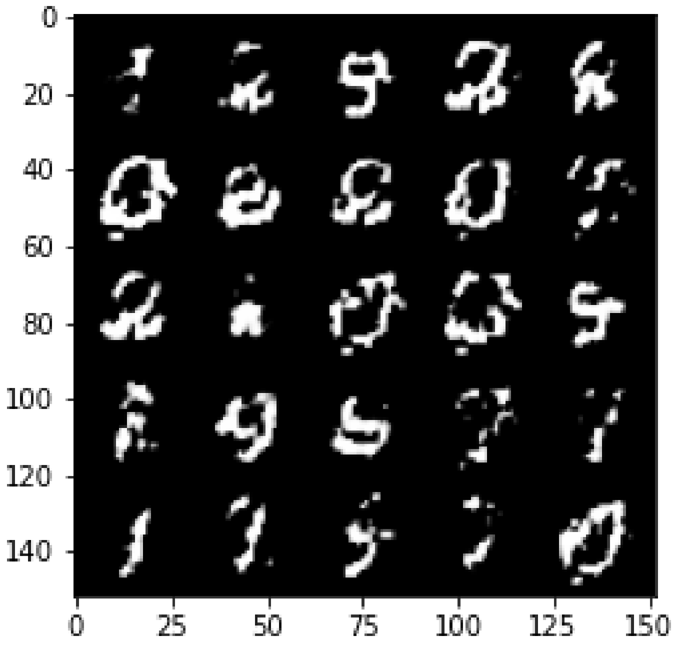
```
Epoch 6, Step 3000 -> Generator loss: 1.2271358238756669, discriminator loss:
0.48467371189594294
```



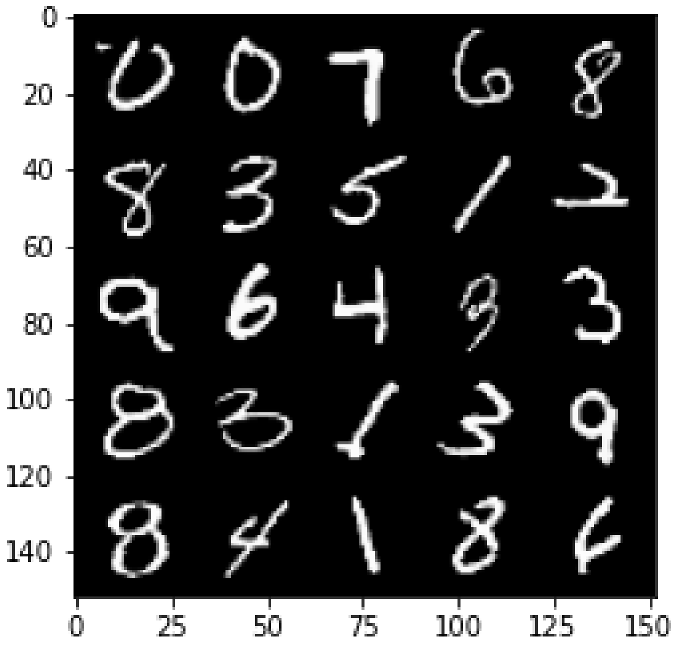
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:54<00:00,  8.62it/s]
 46%|       | 217/469 [00:30<00:34,  7.27it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 7, Step 3500 -> Generator loss: 1.0086355640888205, discriminator loss:
0.5599917694926257
```



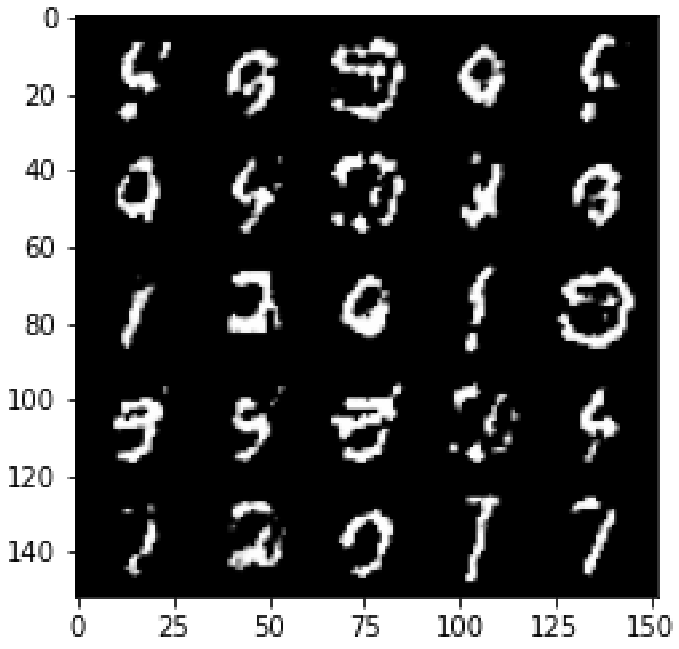
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



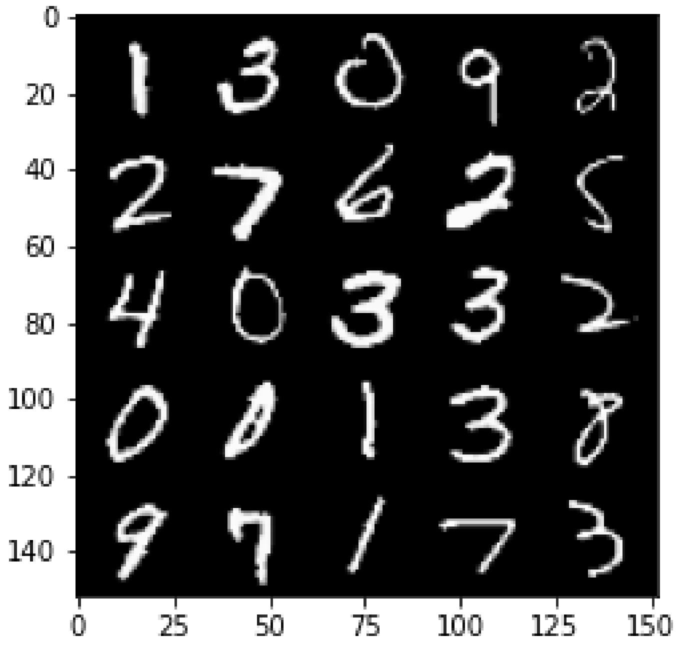
```
100%|      | 469/469 [01:06<00:00,  7.03it/s]
```

```
 53%|       | 248/469 [00:35<00:33,  6.67it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 8, Step 4000 -> Generator loss: 0.9030653799474251, discriminator loss:
0.6073752558827398
```

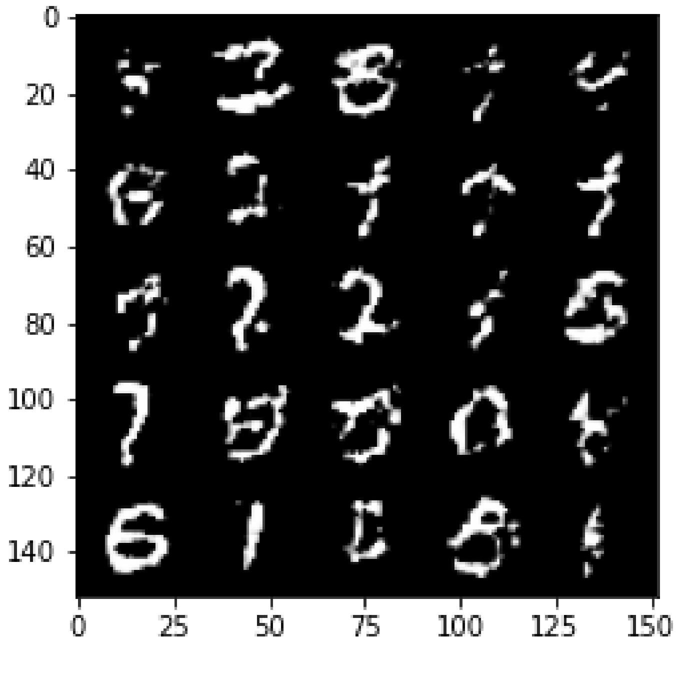


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

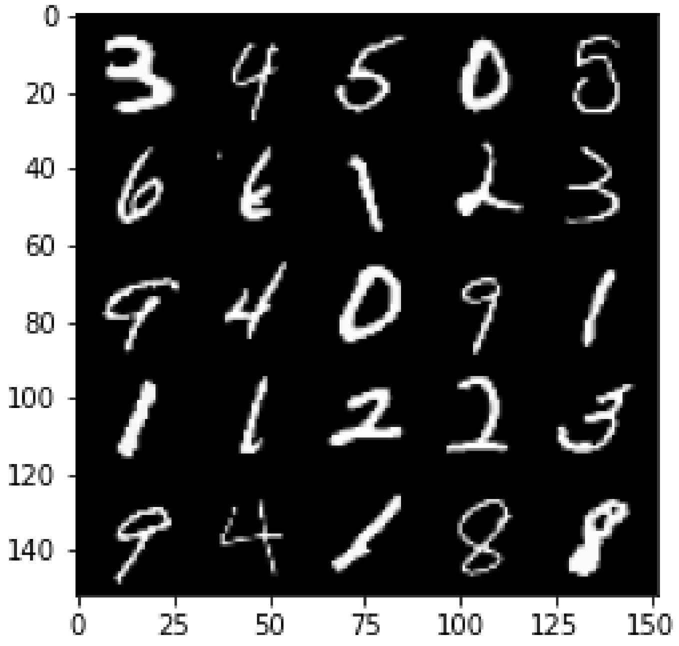


```
100%|      | 469/469 [01:10<00:00,  6.63it/s]
 59%|       | 279/469 [00:51<00:34,  5.48it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

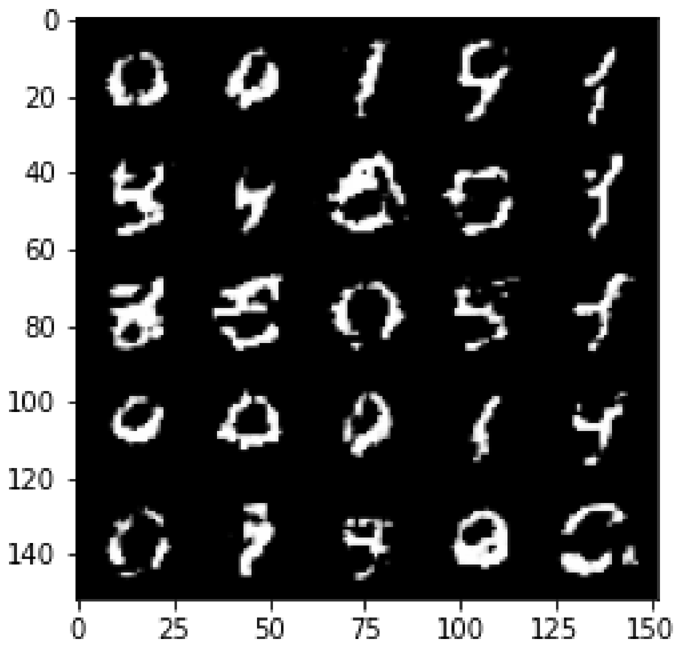
```
Epoch 9, Step 4500 -> Generator loss: 0.8391644552350038, discriminator loss:
0.6280971872806546
```



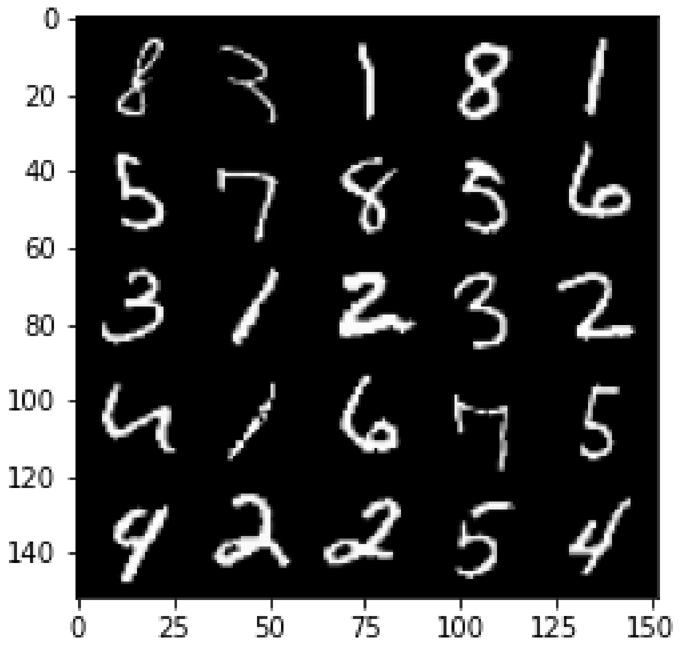
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|     | 469/469 [01:27<00:00,  5.38it/s]
 66%|      | 310/469 [01:02<00:30,  5.15it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 10, Step 5000 -> Generator loss: 0.822732839822769, discriminator loss:
0.6442055417299272
```



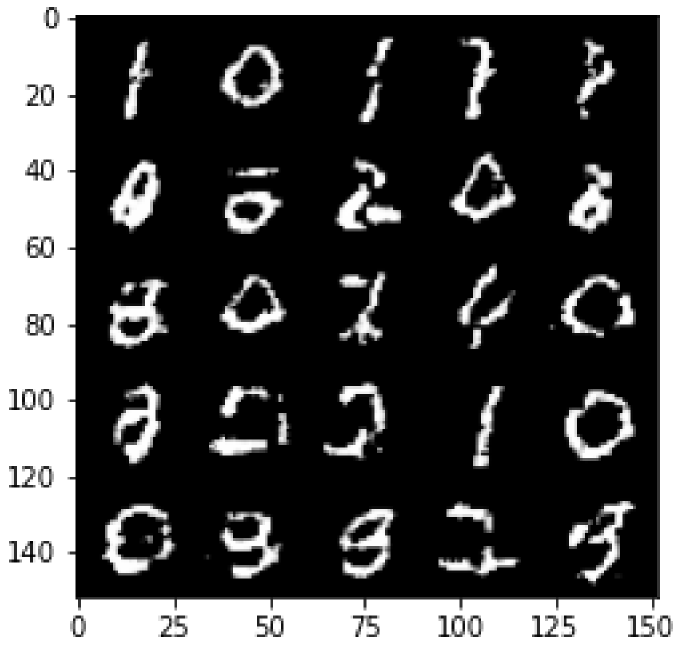
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



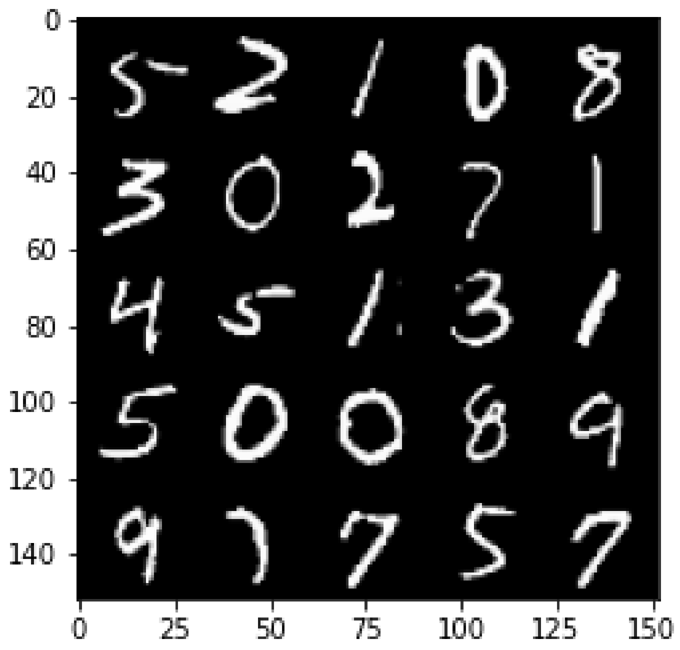
```
100%|     | 469/469 [01:32<00:00,  5.06it/s]
```

```
 73%|      | 341/469 [01:03<00:23,  5.40it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 11, Step 5500 -> Generator loss: 0.8107443764209746, discriminator loss:
0.6574988267421724
```

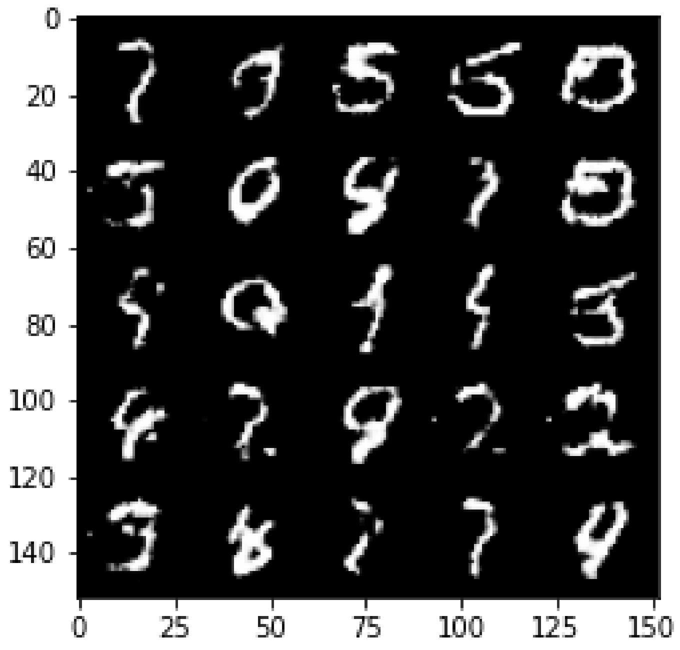


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

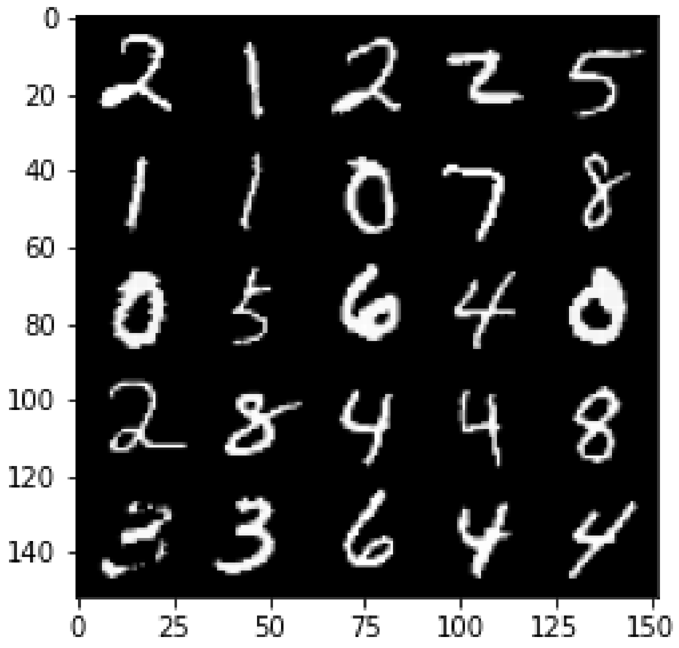


```
100%|      | 469/469 [01:21<00:00,  5.74it/s]
 79%|      | 372/469 [00:52<00:13,  6.97it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 12, Step 6000 -> Generator loss: 0.7844752247929571, discriminator loss:
0.666432977318764
```

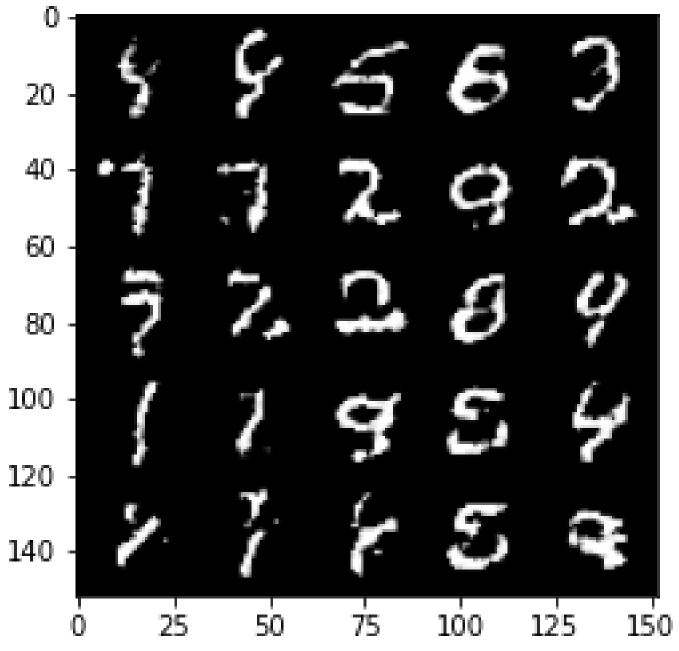


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

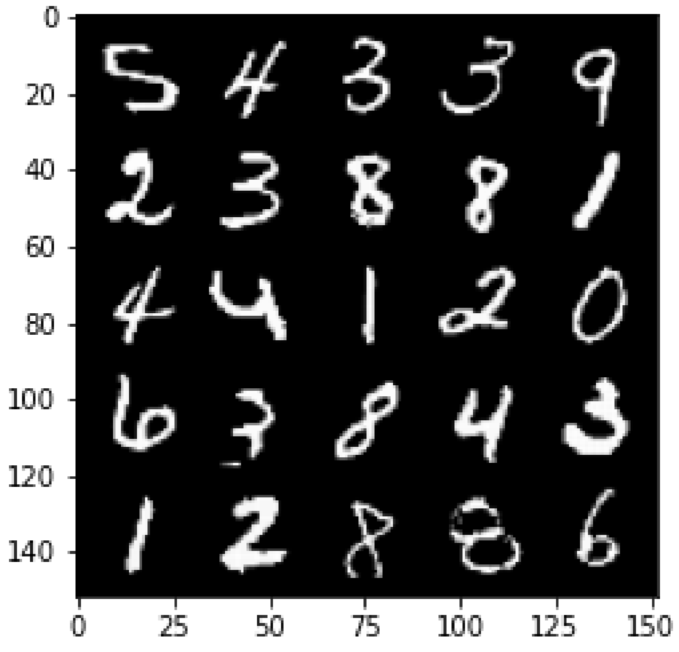


```
100%|      | 469/469 [01:06<00:00,  7.05it/s]
 86%|      | 403/469 [00:56<00:09,  7.18it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 13, Step 6500 -> Generator loss: 0.7667748318910608, discriminator loss:
0.6730719962120058
```



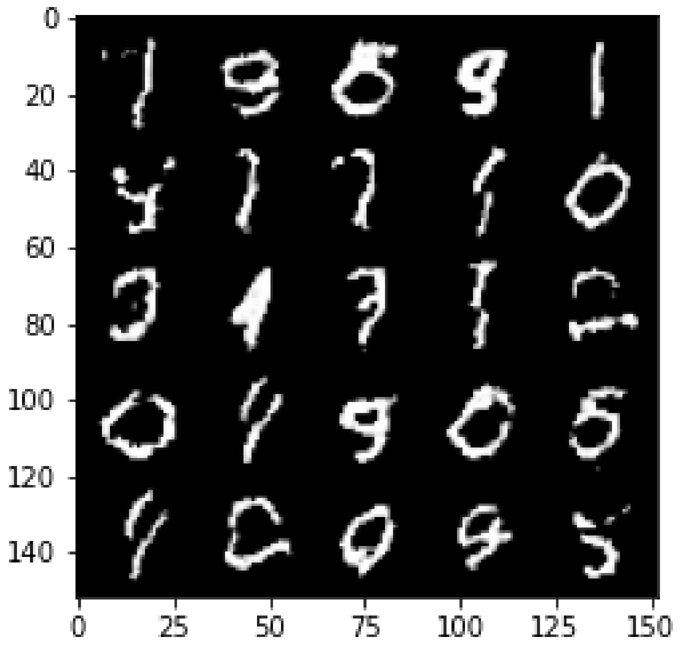
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



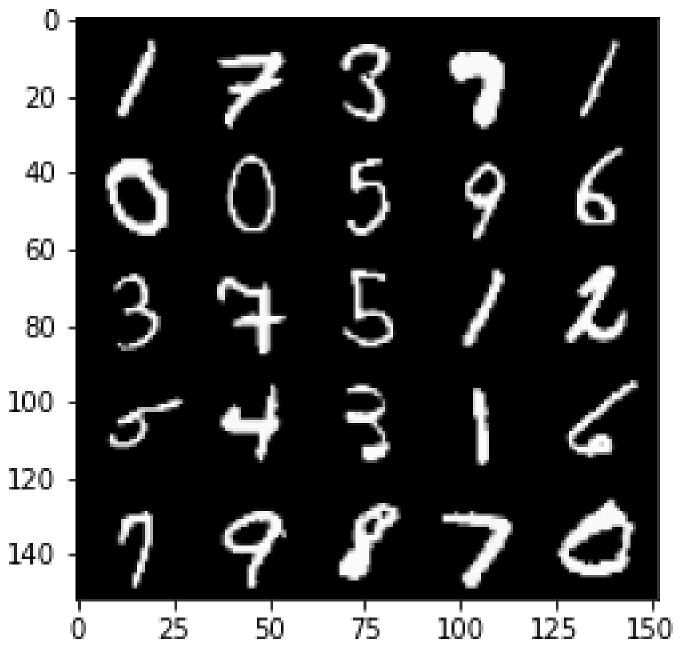
```
100%|      | 469/469 [01:07<00:00,  6.98it/s]
```

```
 93%|      | 434/469 [01:09<00:06,  5.21it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 14, Step 7000 -> Generator loss: 0.7593137623071661, discriminator loss:
0.681104696989059
```

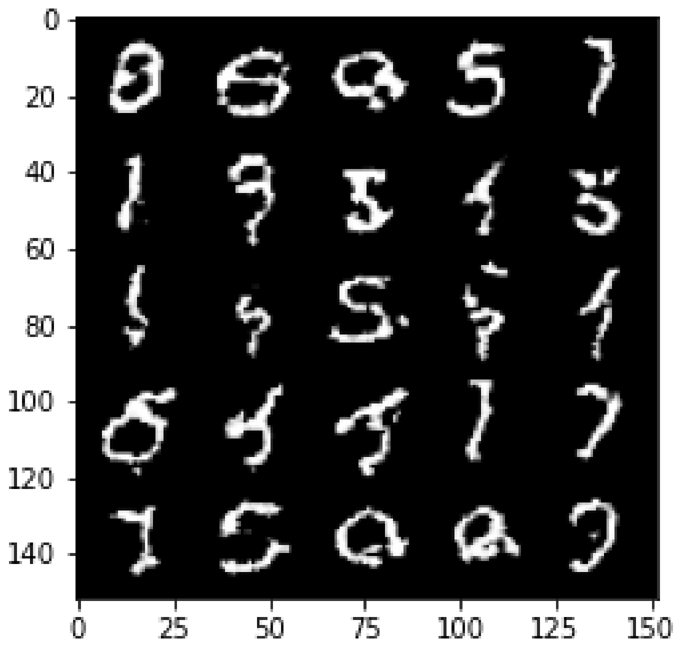


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

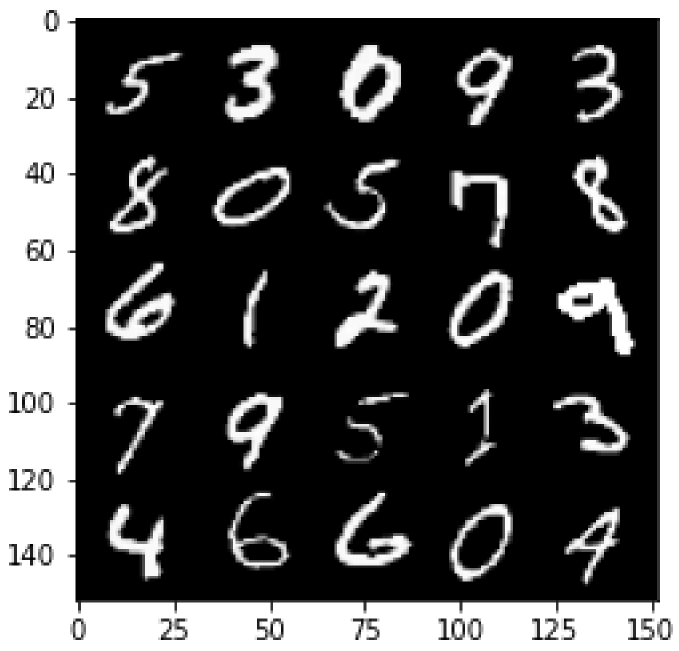


```
100%|          | 469/469 [01:17<00:00,  6.08it/s]
 99%|          | 465/469 [01:16<00:00,  6.49it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

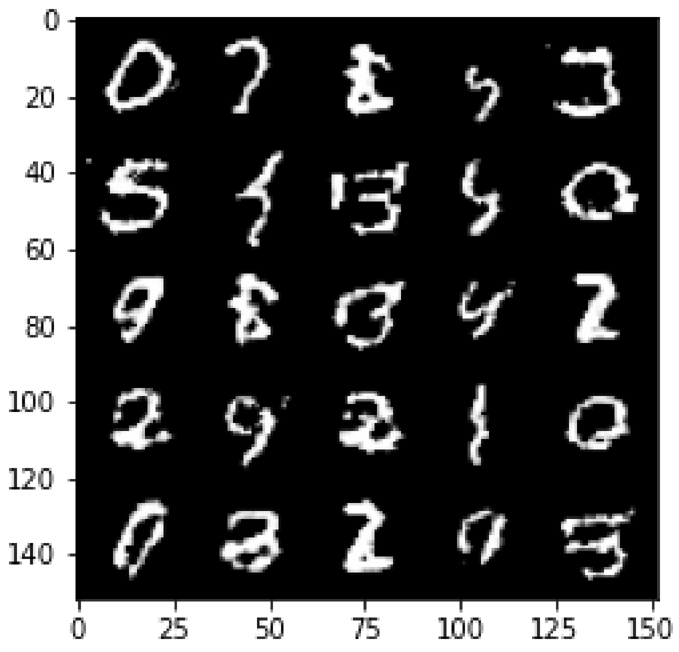
```
Epoch 15, Step 7500 -> Generator loss: 0.7511761513948445, discriminator loss:
0.6830425997972488
```



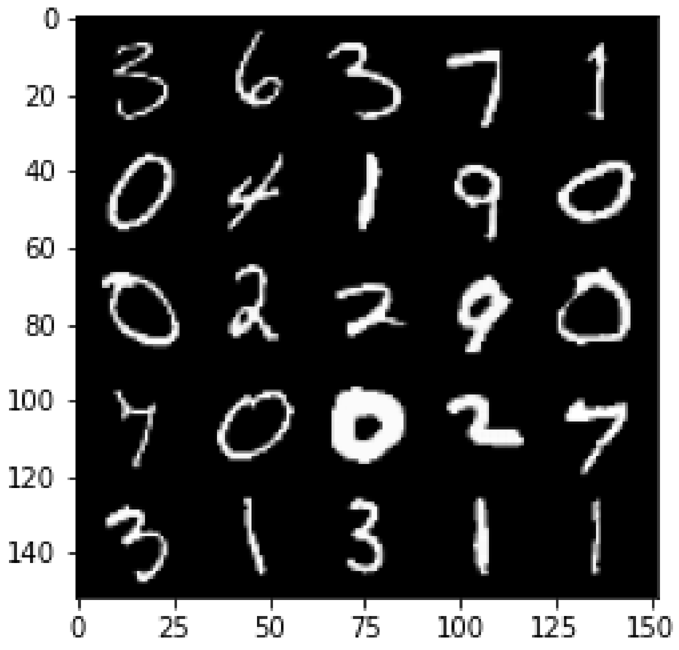
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [01:17<00:00,  6.06it/s]
100%|      | 469/469 [01:07<00:00,  6.93it/s]
  6%|          | 27/469 [00:03<01:03,  7.00it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).

Epoch 17, Step 8000 -> Generator loss: 0.7392115812301641, discriminator loss:
0.6861208425760269
```



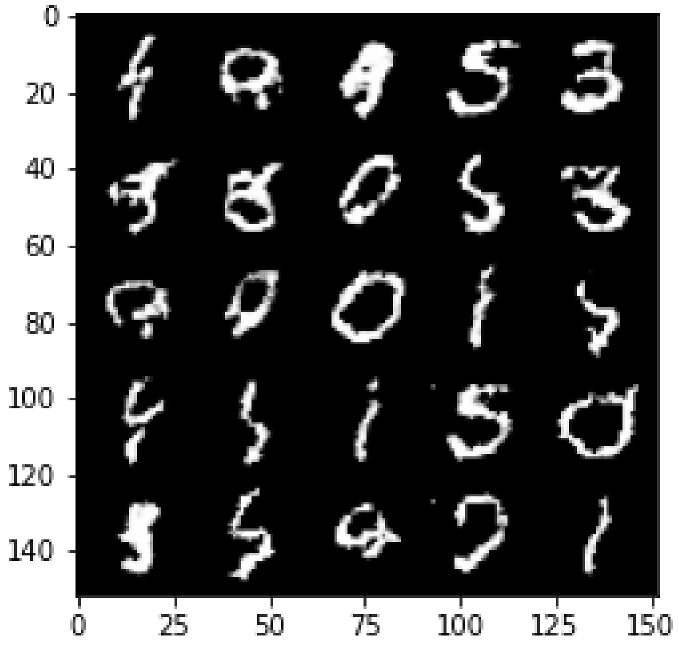
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



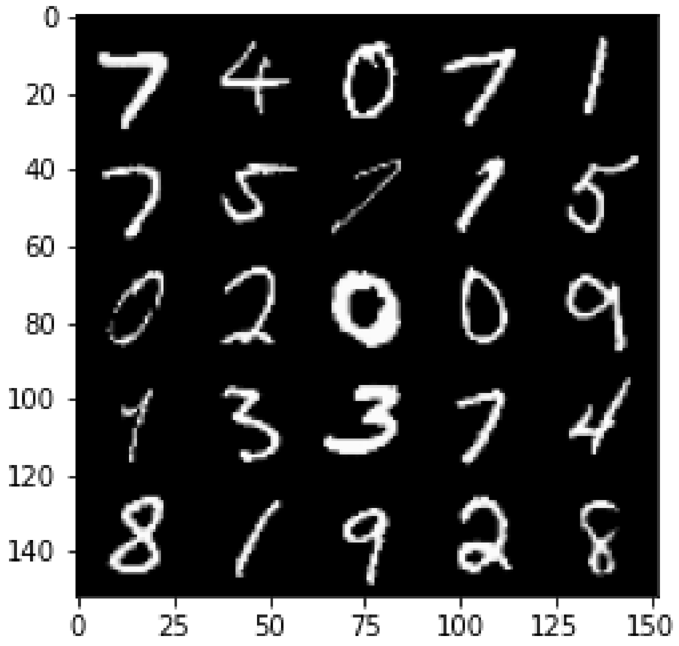
```
100%|      | 469/469 [01:07<00:00,  6.97it/s]
```

```
 12%|          | 58/469 [00:07<00:54,  7.50it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

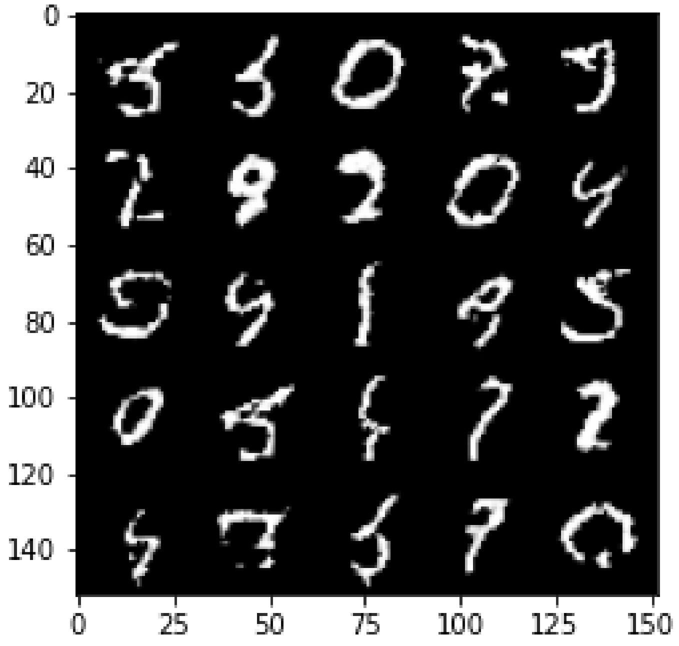
```
Epoch 18, Step 8500 -> Generator loss: 0.7386610203385342, discriminator loss:
0.6857267858982088
```



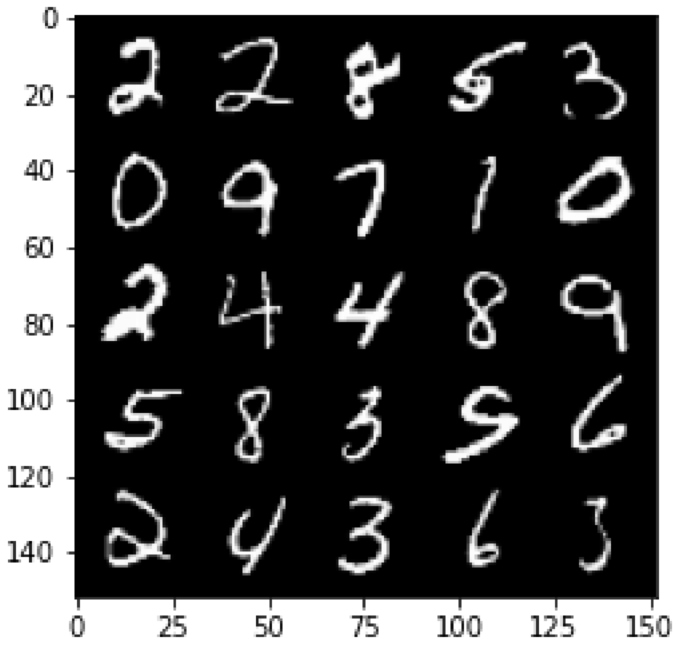
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:53<00:00,  8.78it/s]
 19%|         | 89/469 [00:09<00:40,  9.37it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).

Epoch 19, Step 9000 -> Generator loss: 0.7353383357524873, discriminator loss:
0.6881744418144234
```

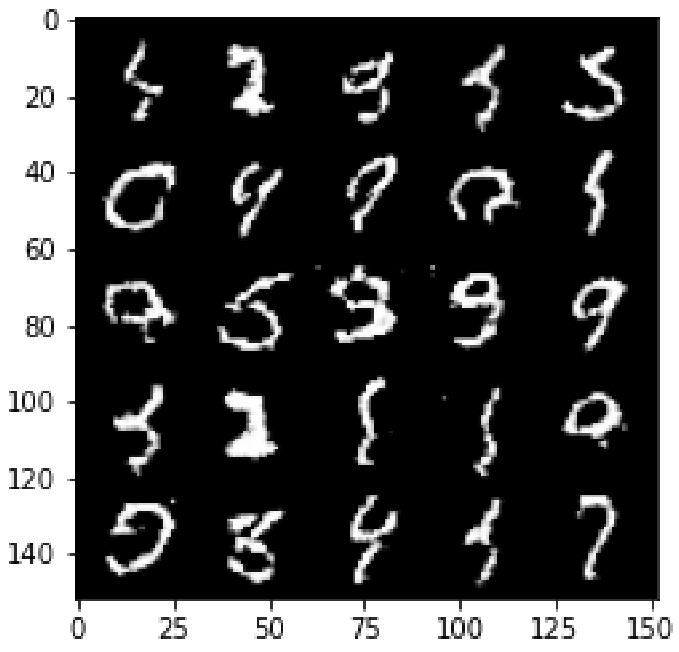


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

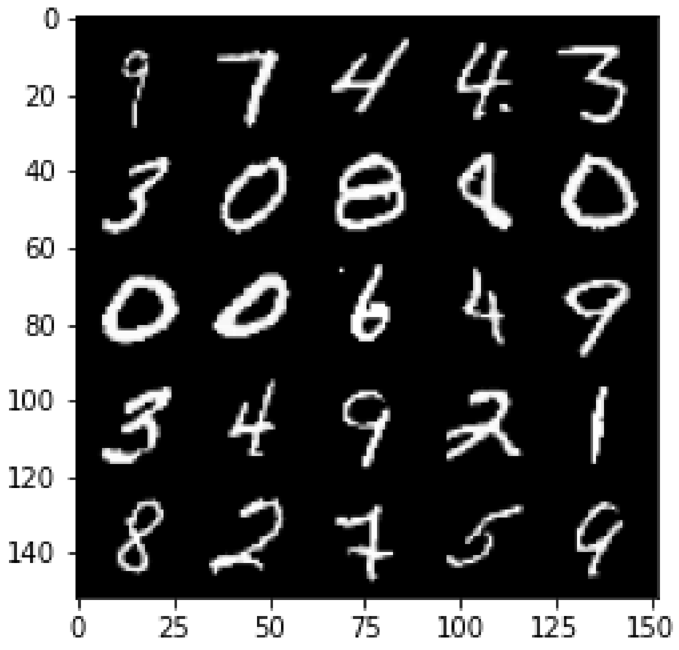


```
100%|      | 469/469 [00:47<00:00,  9.92it/s]
 26%|         | 120/469 [00:11<00:33, 10.29it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 20, Step 9500 -> Generator loss: 0.7269747749567024, discriminator loss:
0.691909653782845
```



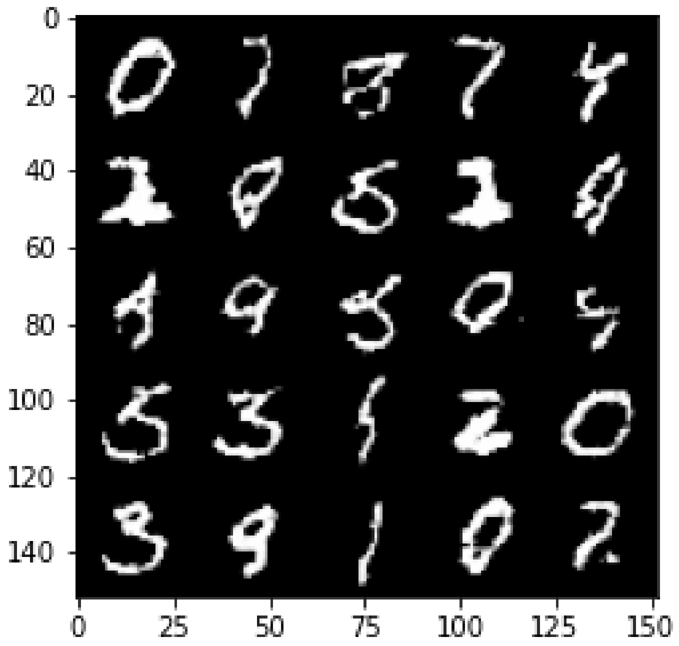
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



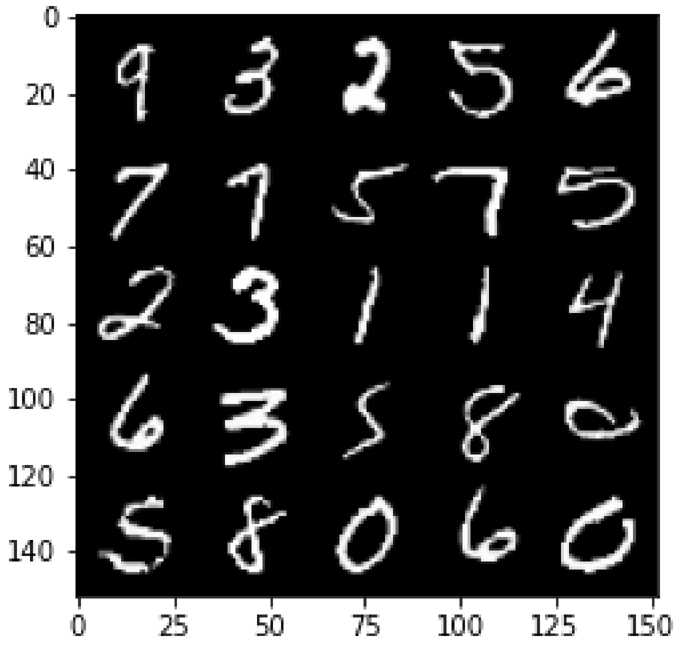
```
100%|      | 469/469 [00:46<00:00, 10.17it/s]
```

```
 32%|        | 151/469 [00:15<00:33,  9.52it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 21, Step 10000 -> Generator loss: 0.7233702152967458, discriminator loss:
0.6927301433086395
```

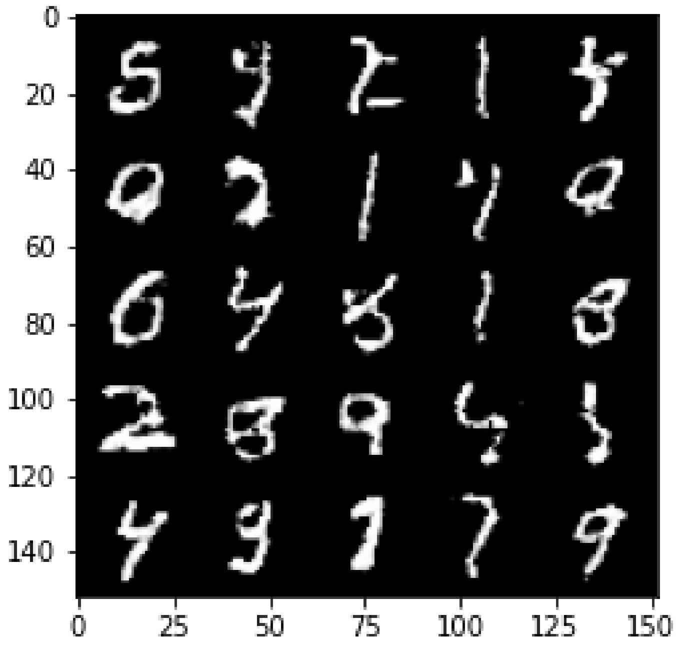


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

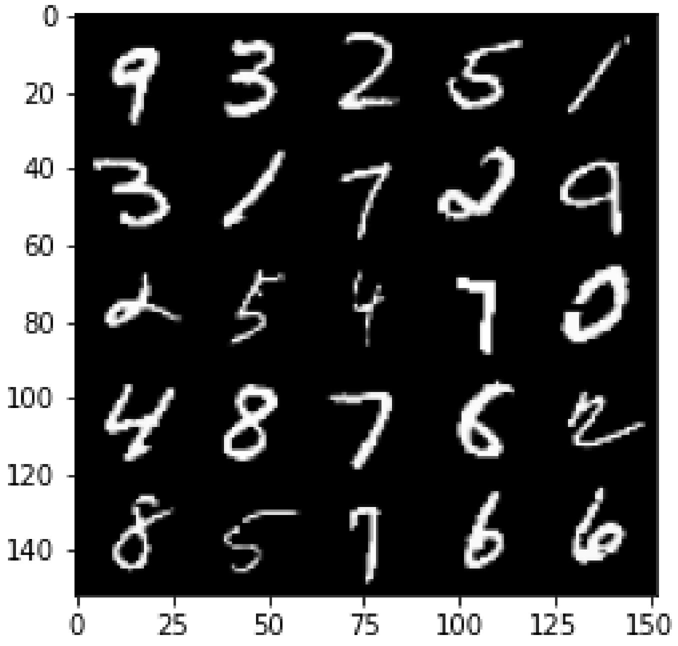


```
100%|      | 469/469 [00:54<00:00,  8.61it/s]
 39%|        | 182/469 [00:22<00:34,  8.33it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 22, Step 10500 -> Generator loss: 0.7203601363897322, discriminator loss:
0.6930514508485797
```

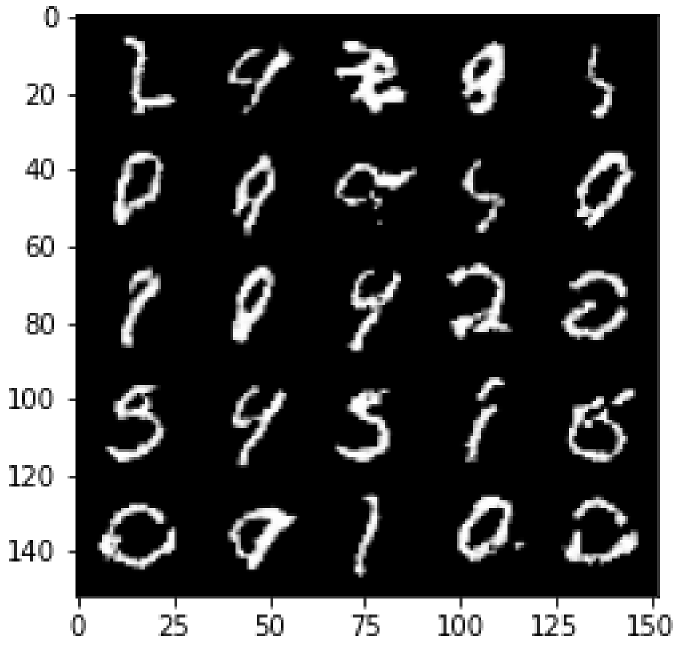


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

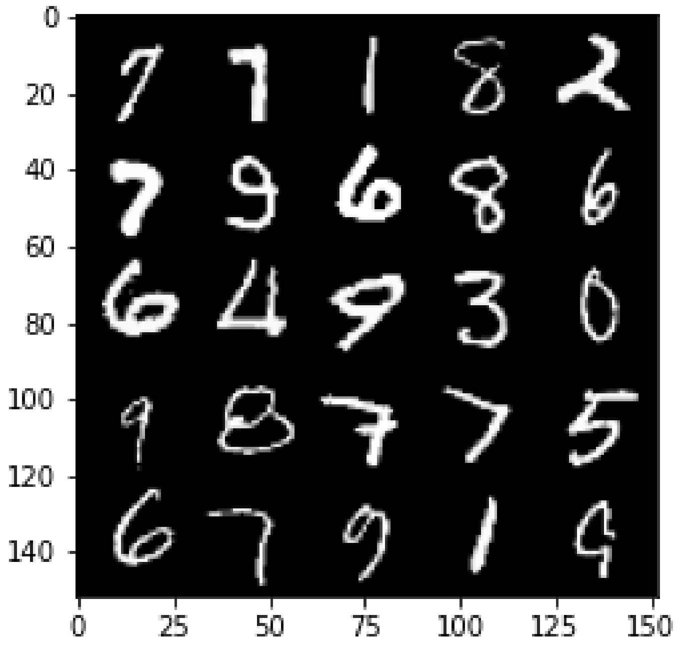


```
100%|     | 469/469 [00:58<00:00,  8.05it/s]
 45%|       | 213/469 [00:25<00:30,  8.26it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 23, Step 11000 -> Generator loss: 0.7221276949644088, discriminator loss:
0.6929171969890593
```



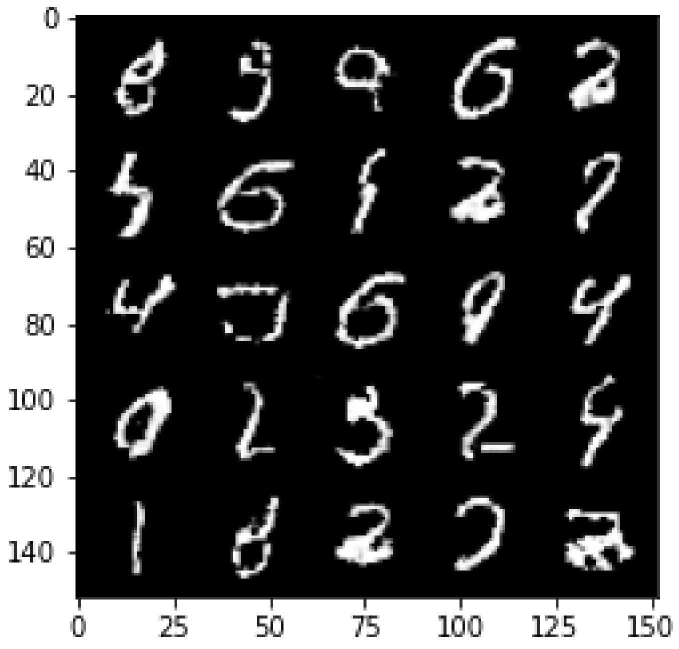
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



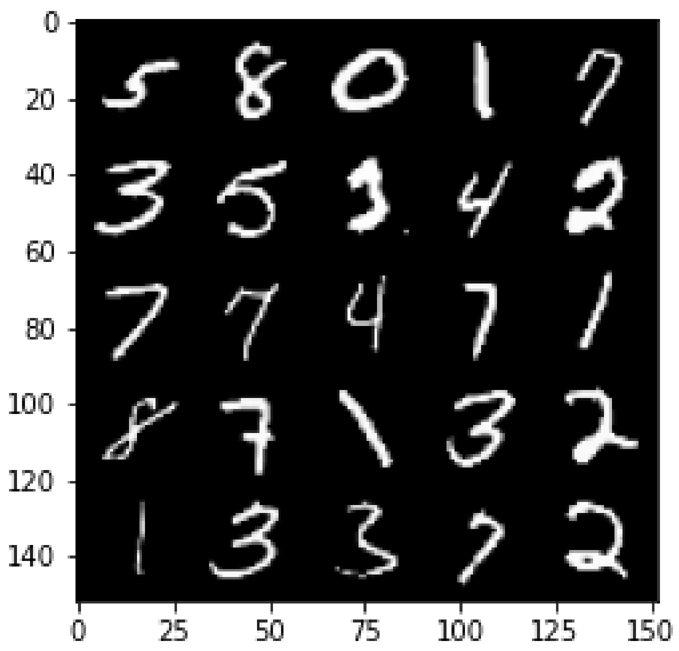
```
100%|      | 469/469 [00:56<00:00,  8.31it/s]
```

```
 52%|       | 244/469 [00:28<00:27,  8.09it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 24, Step 11500 -> Generator loss: 0.7162965229153634, discriminator loss:
0.6946918590068811
```

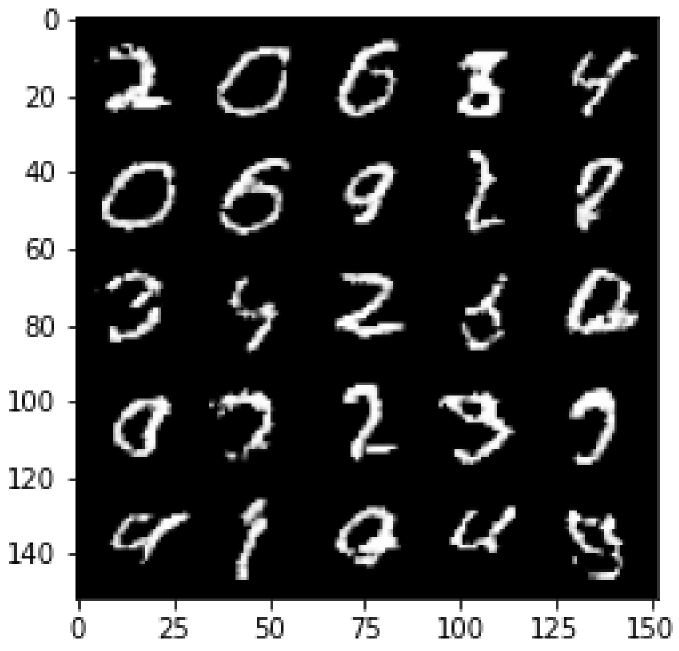


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

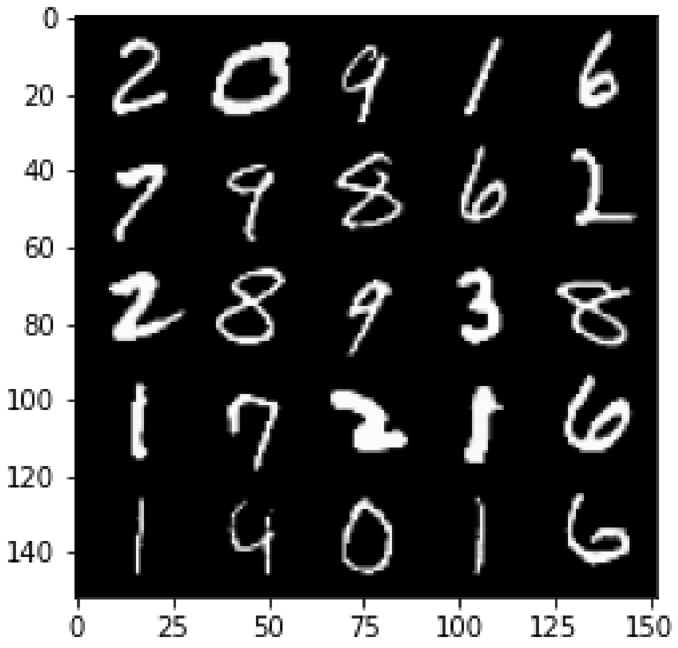


```
100%|      | 469/469 [00:55<00:00,  8.47it/s]
 59%|       | 275/469 [00:31<00:22,  8.52it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

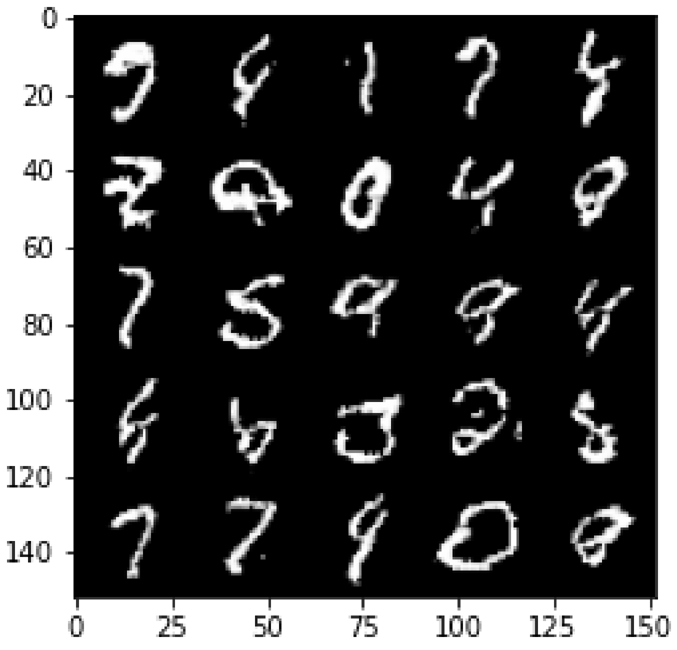
```
Epoch 25, Step 12000 -> Generator loss: 0.7143576785326011, discriminator loss:
0.6947503319978722
```



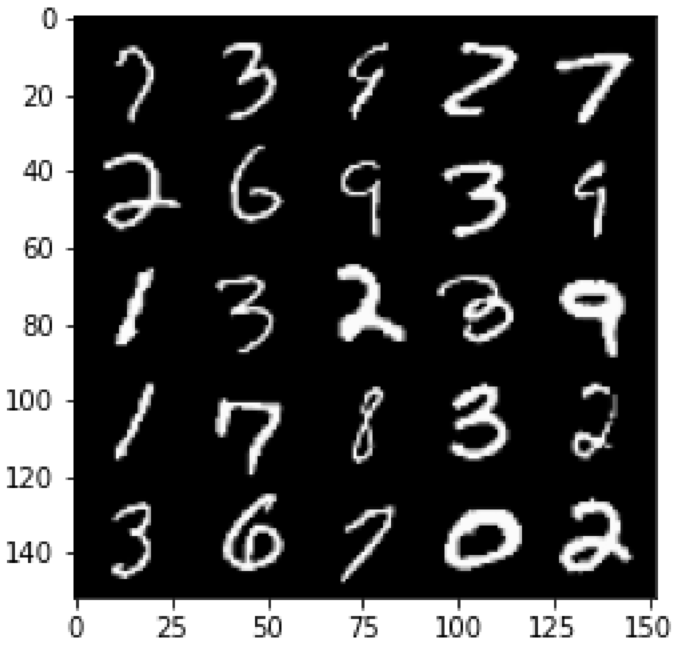
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:54<00:00,  8.67it/s]
 65%|      | 306/469 [00:35<00:18,  8.81it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 26, Step 12500 -> Generator loss: 0.7108955814838401, discriminator loss:
0.6974525845050806
```



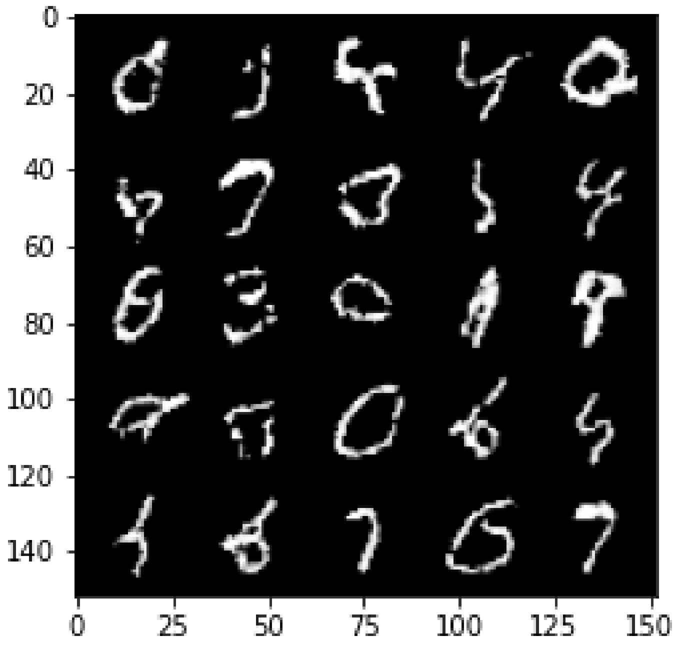
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



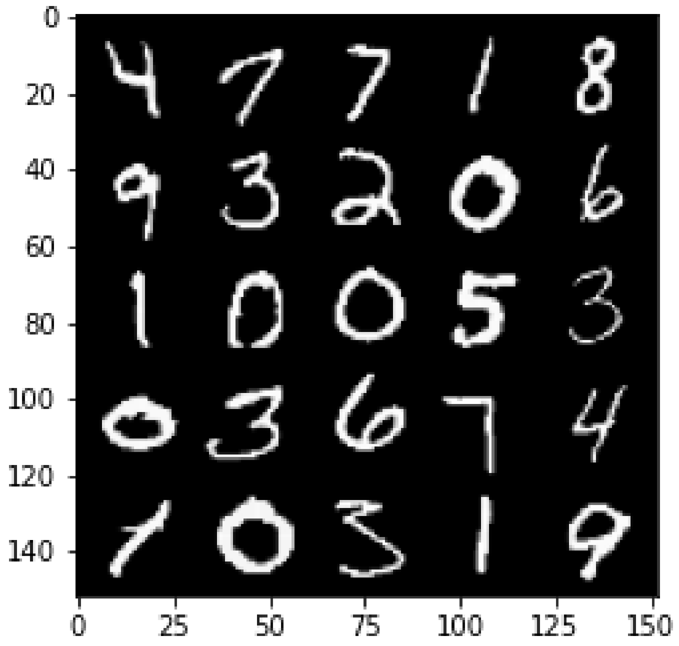
```
100%|      | 469/469 [00:54<00:00,  8.68it/s]
```

```
 72%|      | 337/469 [00:38<00:17,  7.42it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 27, Step 13000 -> Generator loss: 0.7100302911996841, discriminator loss:
0.6971674134731294
```

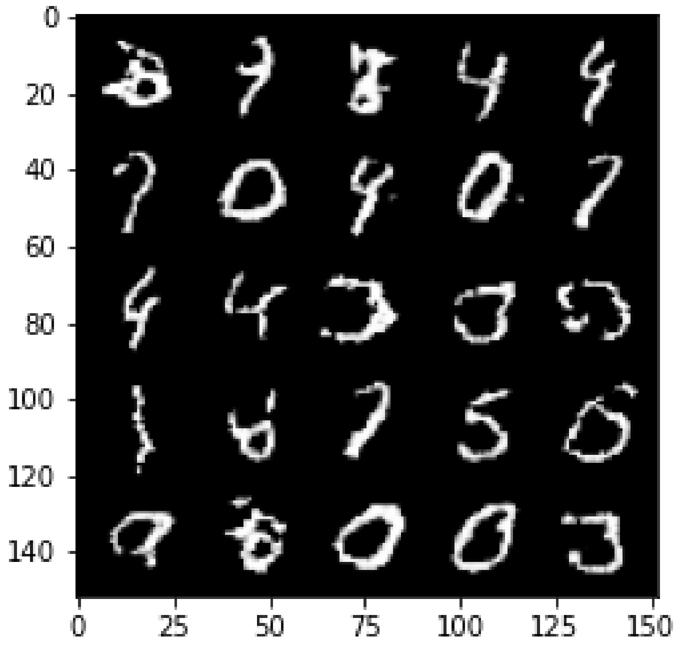


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

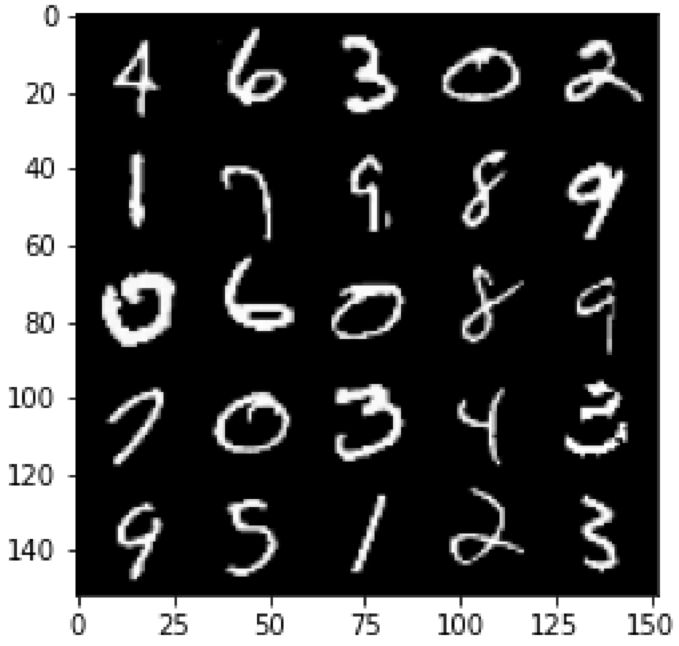


```
100%|      | 469/469 [00:55<00:00,  8.40it/s]
 78%|      | 368/469 [00:43<00:11,  8.83it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 28, Step 13500 -> Generator loss: 0.7079693858623503, discriminator loss:
0.6987180138826371
```

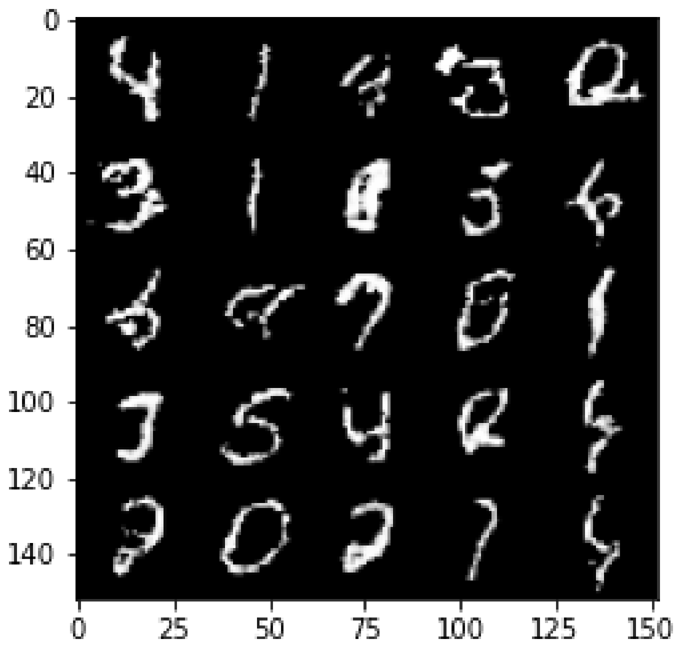


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

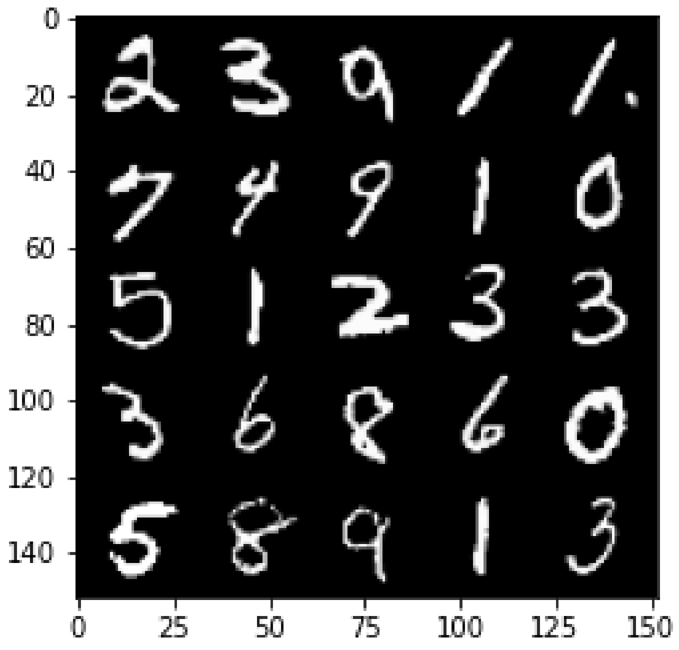


```
100%|      | 469/469 [00:55<00:00,  8.41it/s]
 85%|      | 399/469 [00:46<00:08,  8.71it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 29, Step 14000 -> Generator loss: 0.7079534164667127, discriminator loss:
0.6988920823335653
```



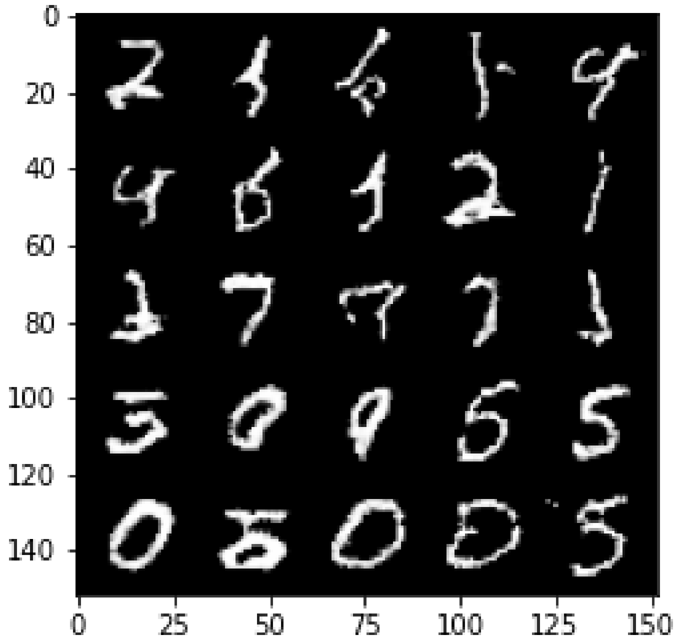
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



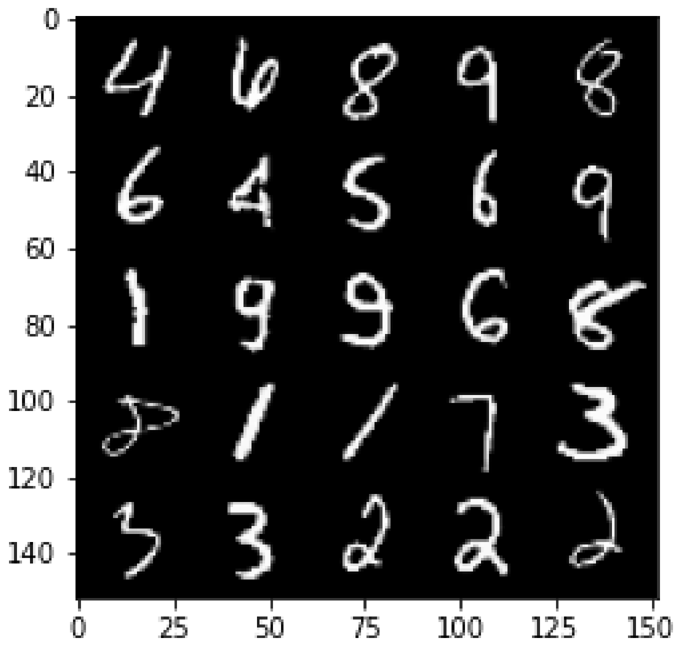
```
100%|      | 469/469 [00:54<00:00,  8.59it/s]
```

```
 92%|      | 430/469 [00:50<00:04,  8.48it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 30, Step 14500 -> Generator loss: 0.7035157251358036, discriminator loss:
0.6993961700201036
```

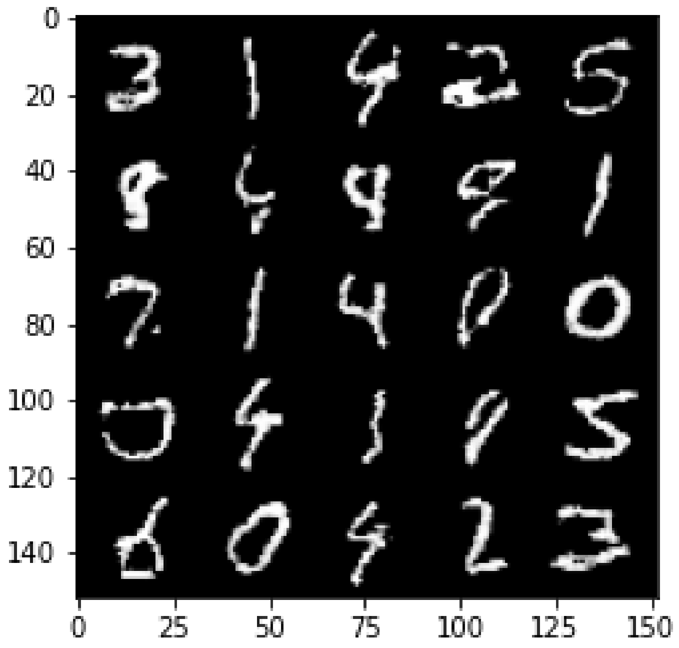


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

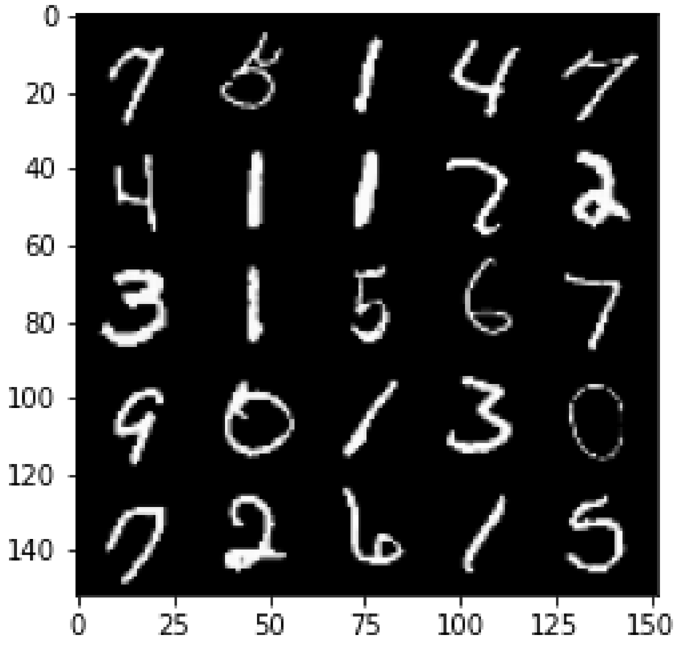


```
100%|      | 469/469 [00:55<00:00,  8.51it/s]
 98%|      | 461/469 [00:54<00:00,  8.52it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

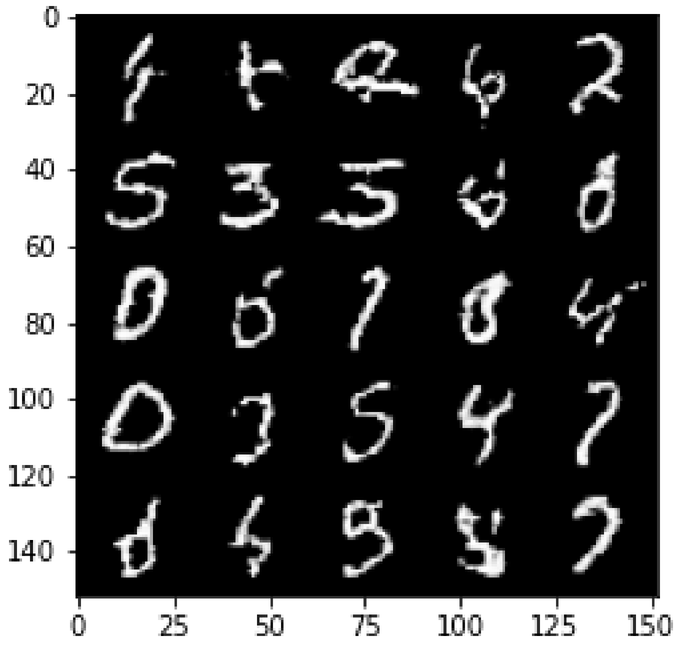
```
Epoch 31, Step 15000 -> Generator loss: 0.703436859726906, discriminator loss:
0.6997093617916114
```



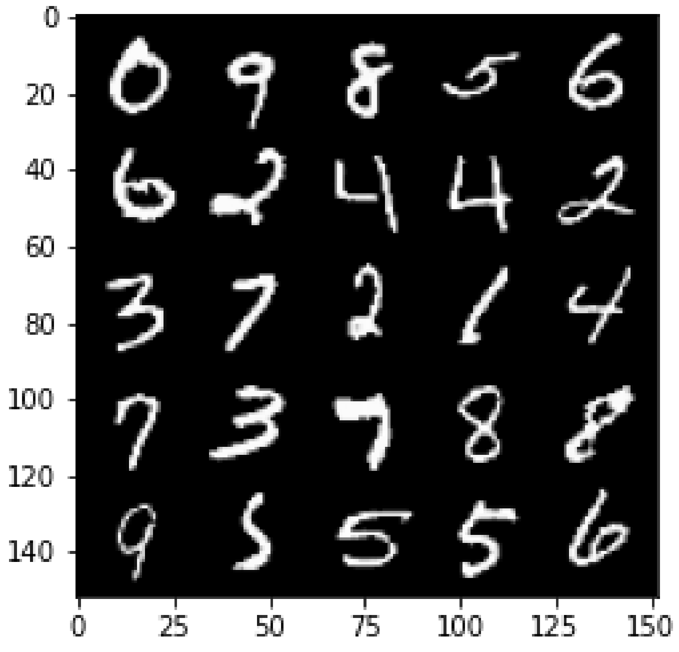
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|     | 469/469 [00:55<00:00,  8.46it/s]
100%|     | 469/469 [00:55<00:00,  8.53it/s]
  5%|         | 23/469 [00:02<00:50,  8.80it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).

Epoch 33, Step 15500 -> Generator loss: 0.7026034195423123, discriminator loss:
0.6990421177148823
```



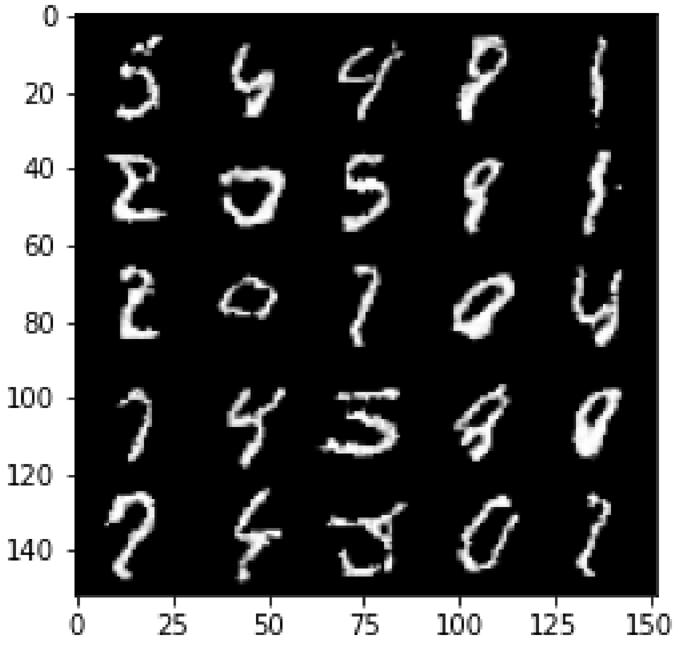
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



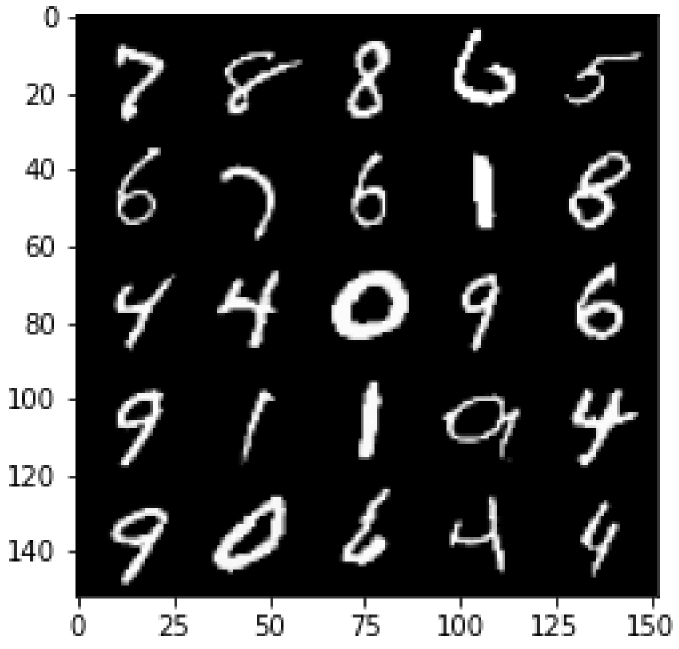
```
100%|      | 469/469 [00:54<00:00,  8.58it/s]
```

```
 12%|          | 54/469 [00:06<00:58,  7.05it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

```
Epoch 34, Step 16000 -> Generator loss: 0.6997083667516711, discriminator loss:
0.6988953154087068
```

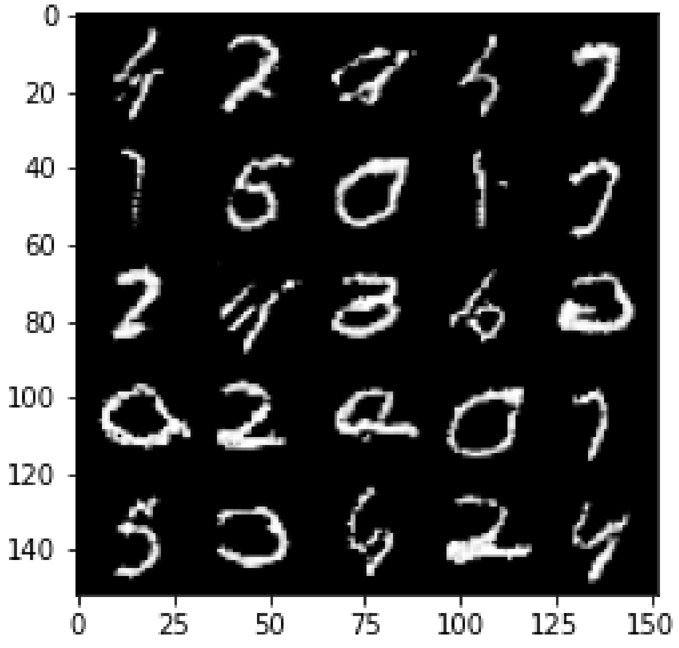


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

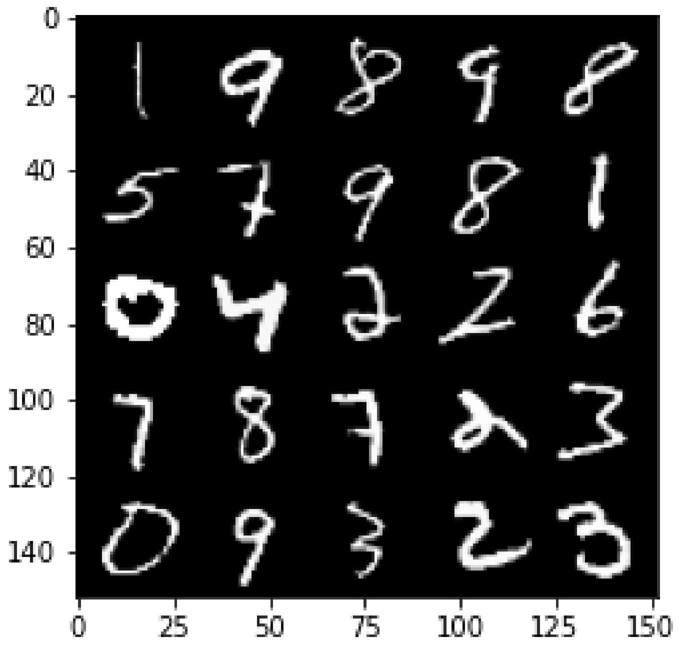


```
100%|      | 469/469 [00:55<00:00,  8.50it/s]
 18%|         | 85/469 [00:09<00:44,  8.70it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

```
Epoch 35, Step 16500 -> Generator loss: 0.7000321176052098, discriminator loss:
0.6997848379611973
```

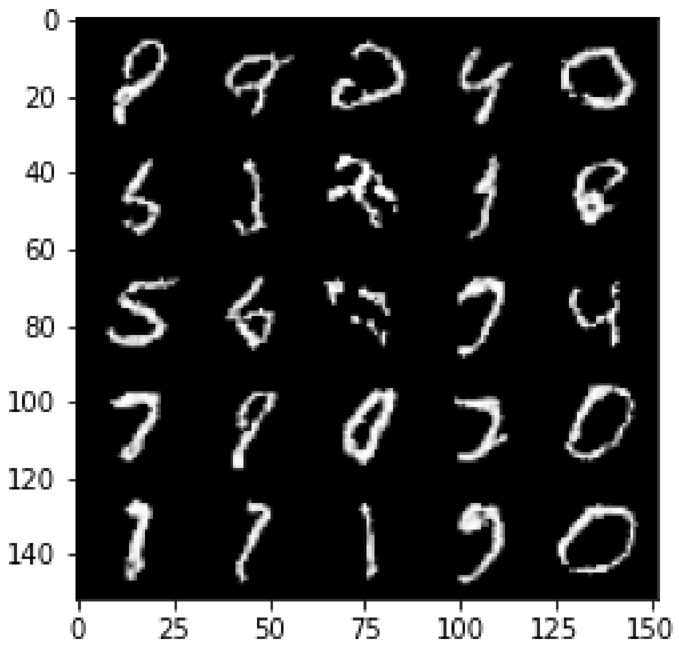


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

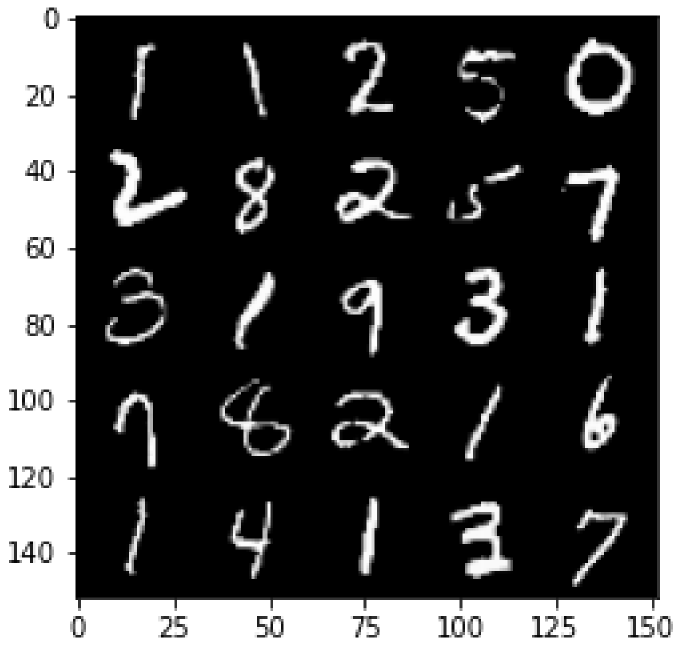


```
100%|      | 469/469 [00:53<00:00,  8.82it/s]
 25%|         | 116/469 [00:12<00:38,  9.15it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 36, Step 17000 -> Generator loss: 0.6970182778835292, discriminator loss:
0.6996576677560801
```



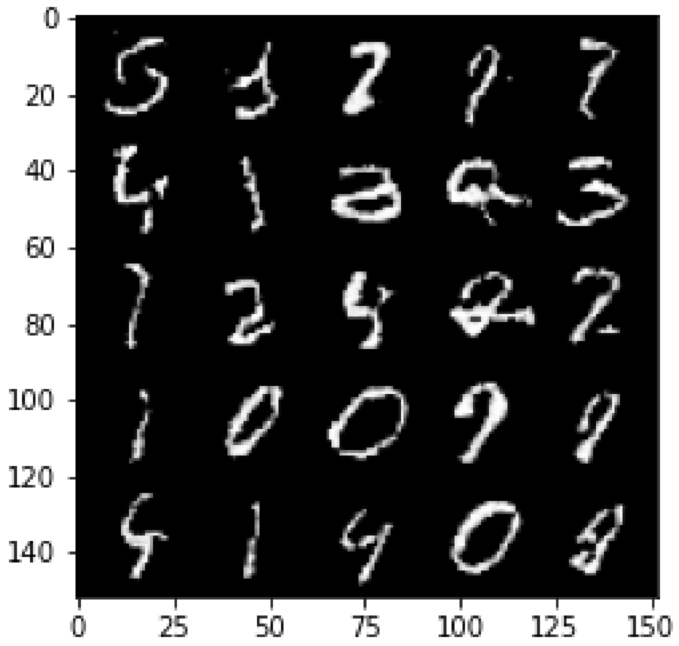
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



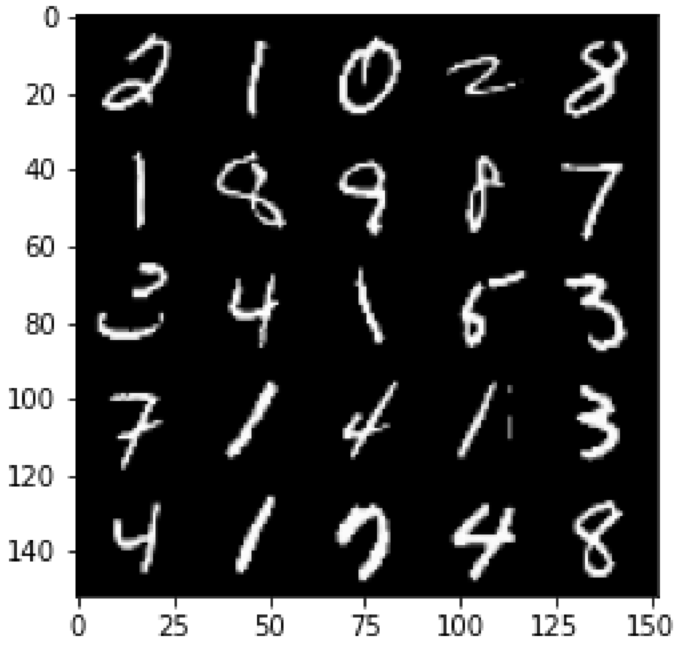
```
100%|      | 469/469 [00:52<00:00,  9.01it/s]
```

```
 31%|        | 147/469 [00:16<00:35,  9.16it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 37, Step 17500 -> Generator loss: 0.6998991723060604, discriminator loss:
0.6996488074064254
```

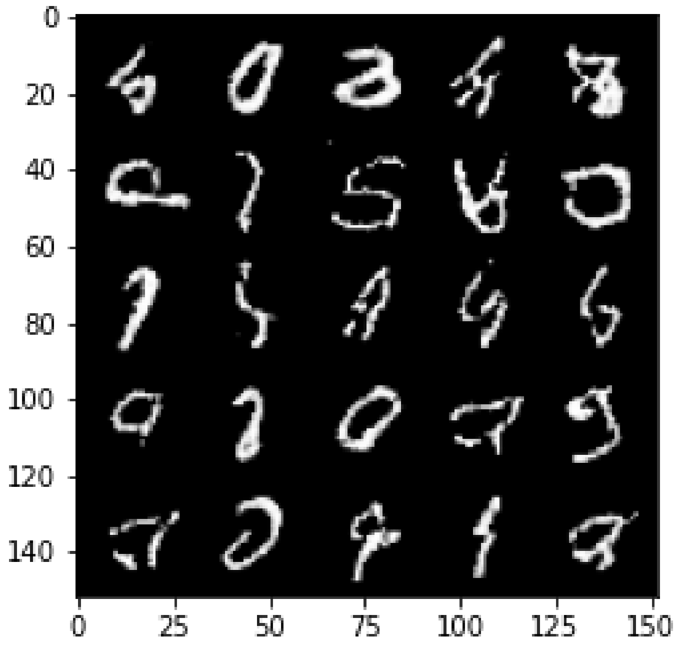


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

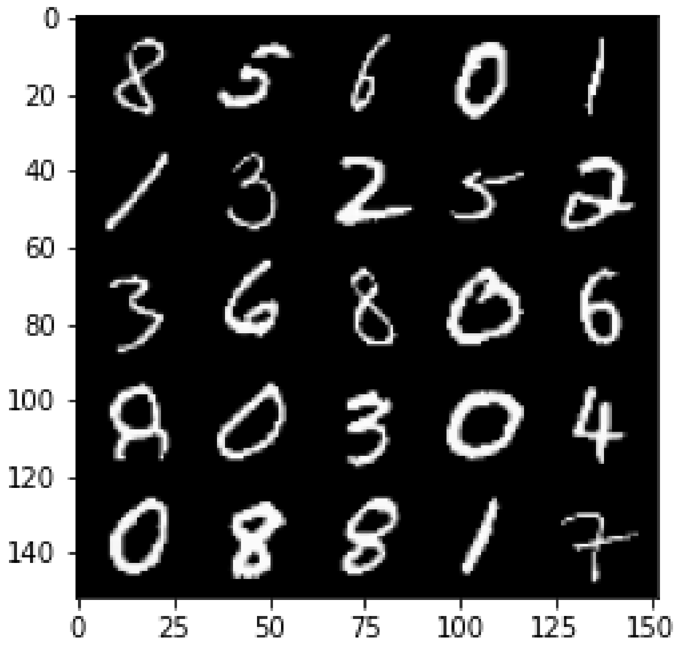


```
100%|      | 469/469 [00:49<00:00,  9.39it/s]
 38%|        | 178/469 [00:19<00:35,  8.22it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 38, Step 18000 -> Generator loss: 0.696147113084793, discriminator loss:
0.6989460996389384
```

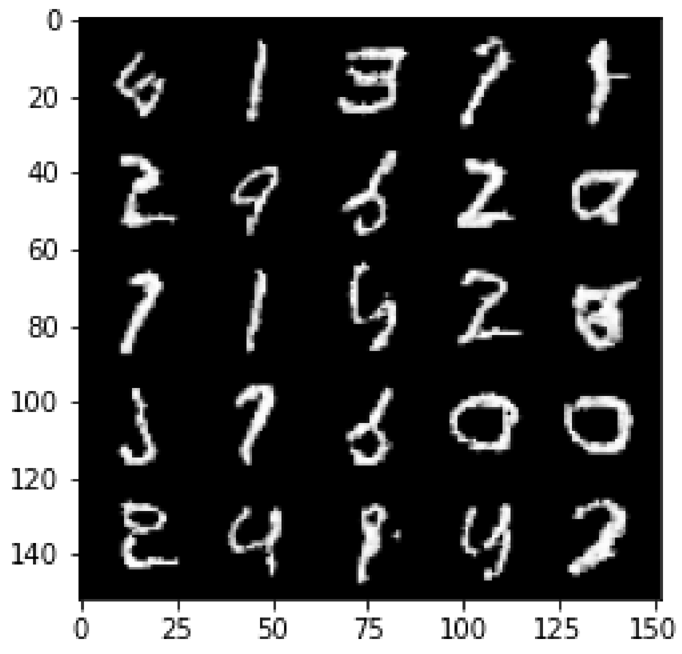


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

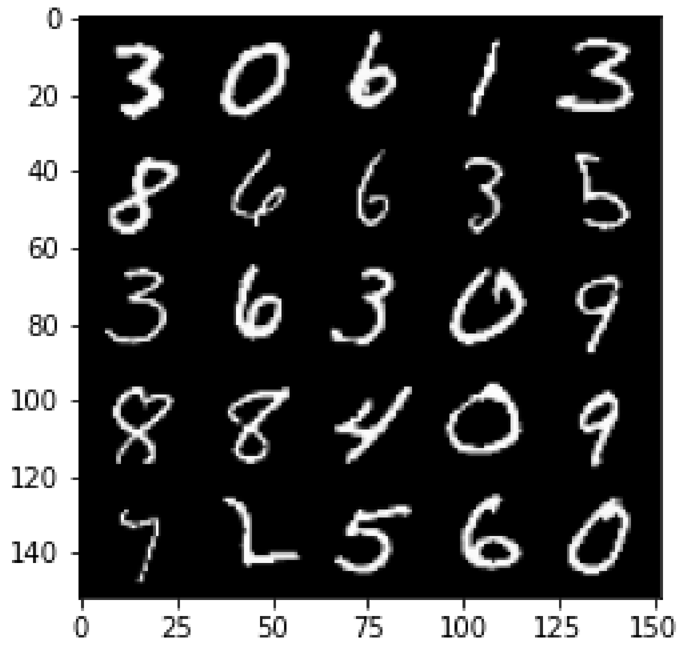


```
100%|      | 469/469 [00:50<00:00,  9.29it/s]
 45%|       | 209/469 [00:20<00:25, 10.30it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 39, Step 18500 -> Generator loss: 0.6968745787143713, discriminator loss:
0.6986745182275785
```



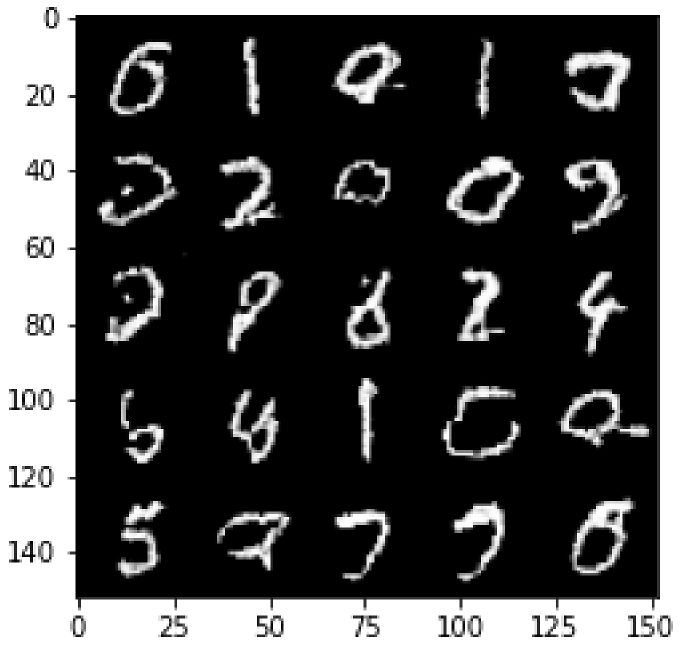
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



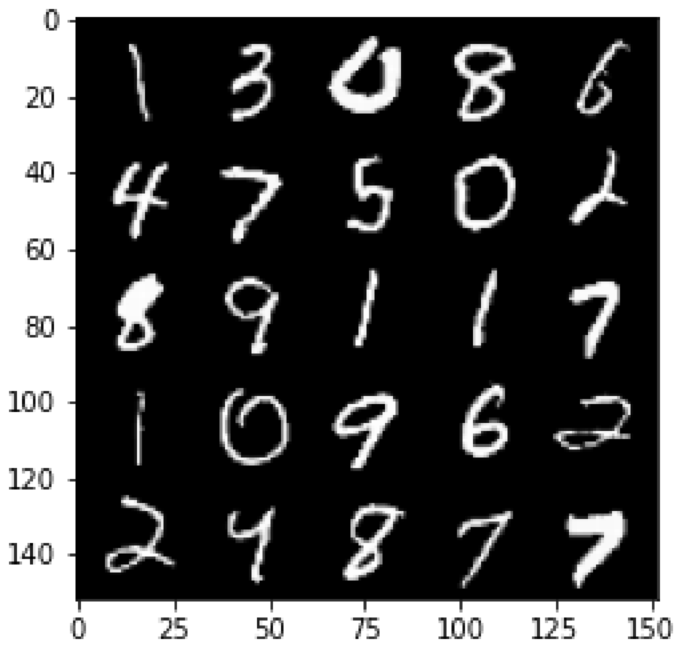
```
100%|      | 469/469 [00:47<00:00,  9.89it/s]
```

```
 51%|         | 240/469 [00:23<00:22, 10.05it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 40, Step 19000 -> Generator loss: 0.6967551032304767, discriminator loss:
0.6985122269392027
```

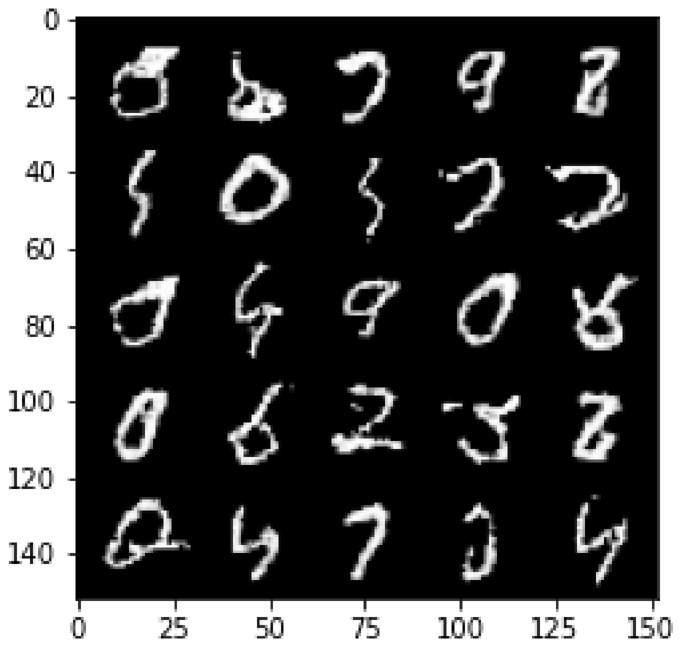


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

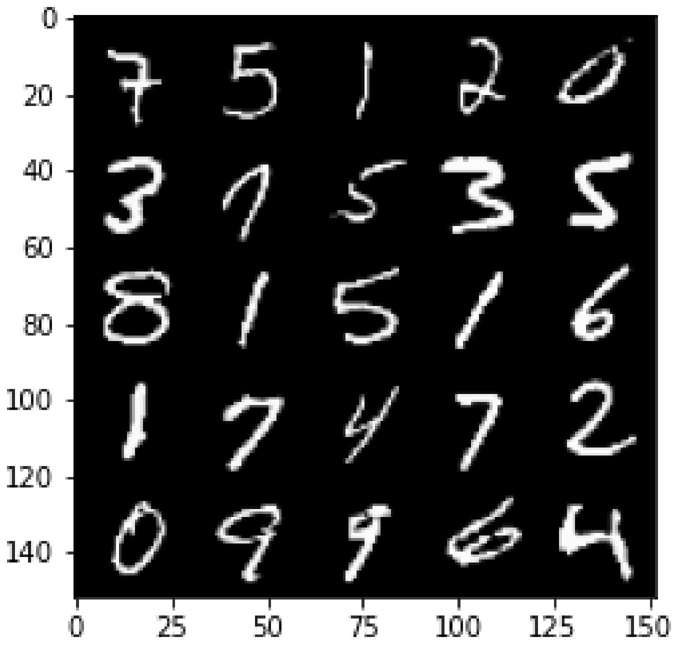


```
100%|      | 469/469 [00:46<00:00, 10.07it/s]
 58%|       | 271/469 [00:26<00:19, 10.08it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 41, Step 19500 -> Generator loss: 0.6949736826419828, discriminator loss:
0.6979883621931077
```

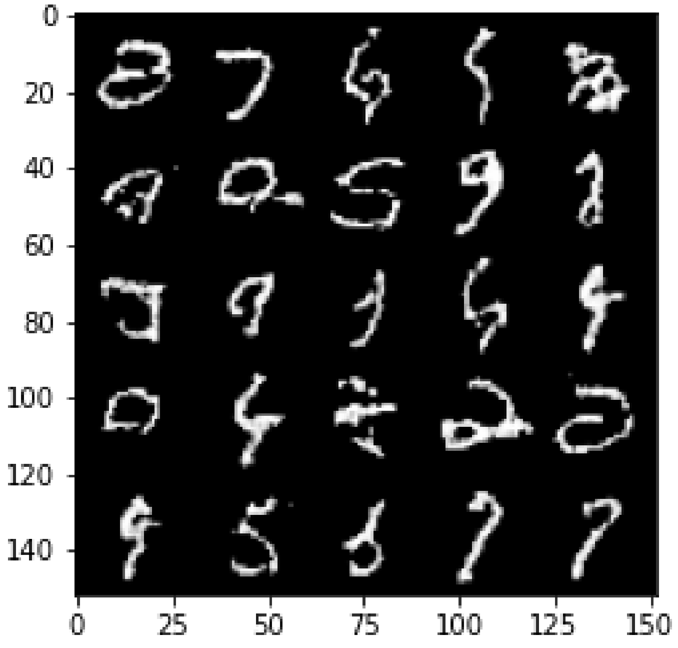


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

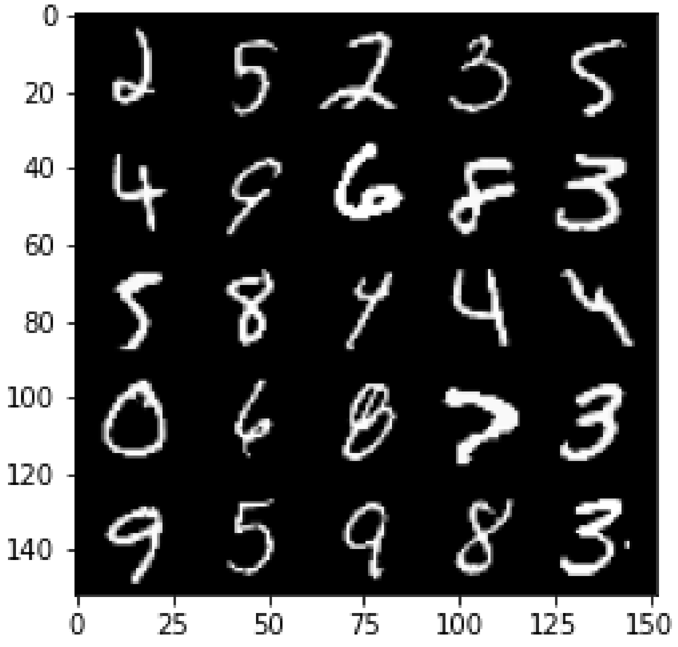


```
100%|      | 469/469 [00:46<00:00, 10.03it/s]
 64%|       | 302/469 [00:29<00:16,  9.98it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 42, Step 20000 -> Generator loss: 0.6961075615882877, discriminator loss:
0.697935058236122
```



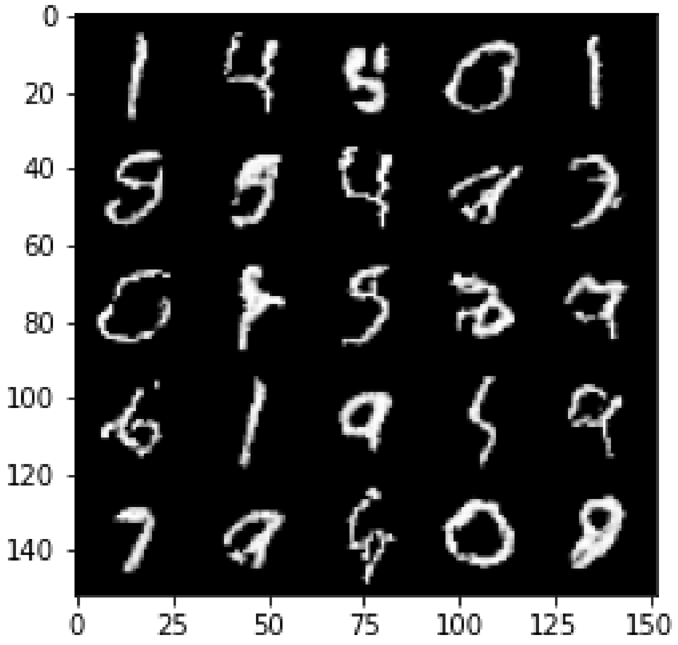
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



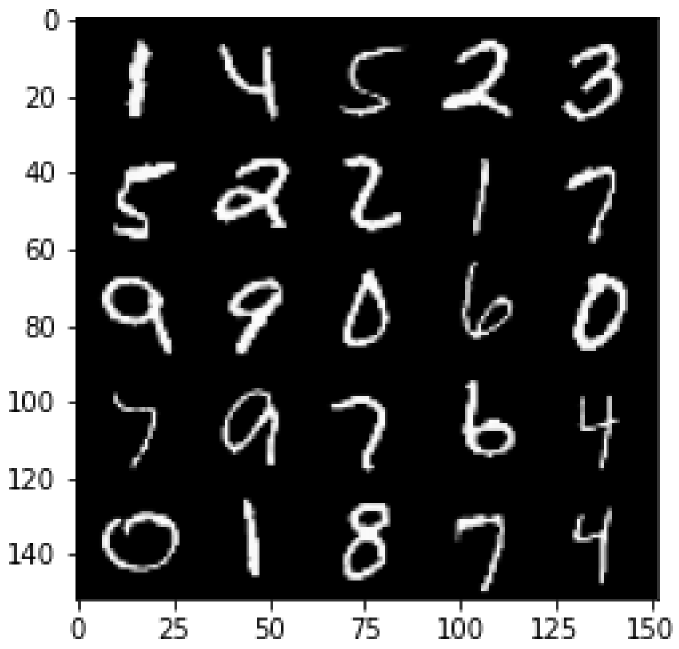
```
100%|      | 469/469 [00:46<00:00, 10.03it/s]
```

```
 71%|       | 333/469 [00:35<00:15,  9.01it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 43, Step 20500 -> Generator loss: 0.6967242122888568, discriminator loss:
0.6978850022554394
```

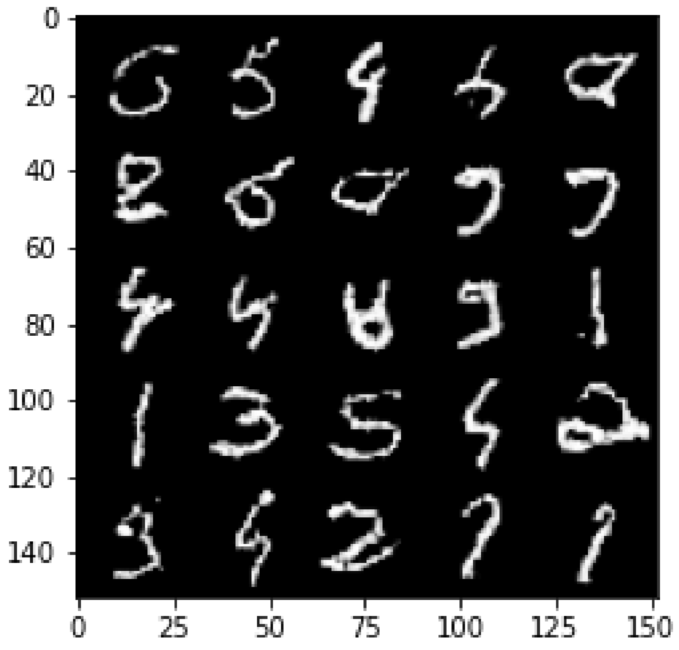


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

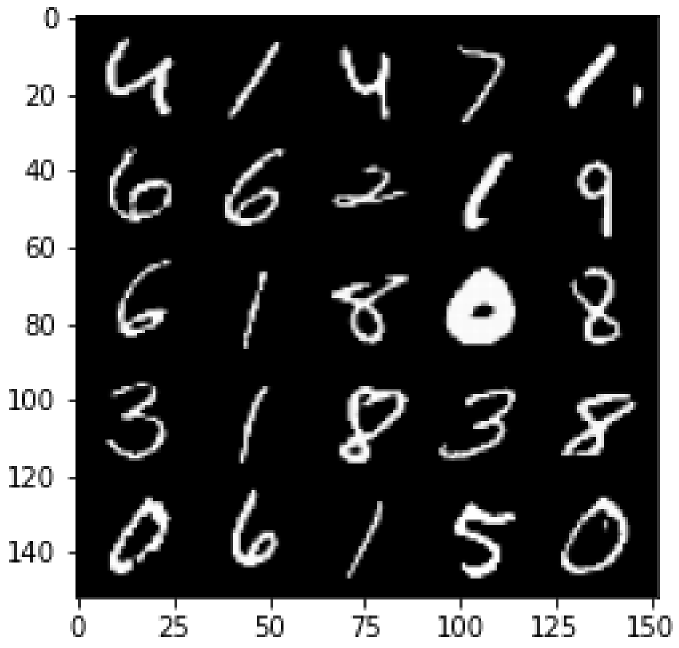


```
100%|      | 469/469 [00:50<00:00,  9.29it/s]
 78%|      | 364/469 [00:40<00:12,  8.21it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

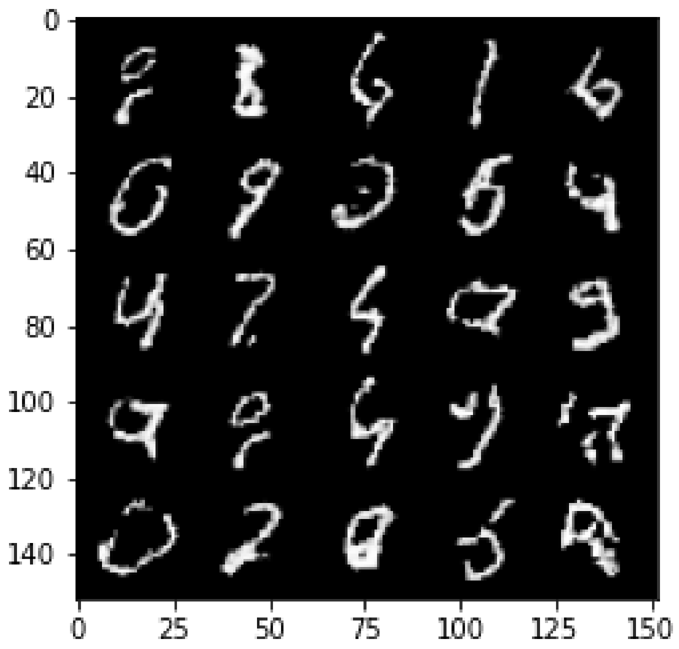
```
Epoch 44, Step 21000 -> Generator loss: 0.6954332612752909, discriminator loss:
0.6970556145906446
```



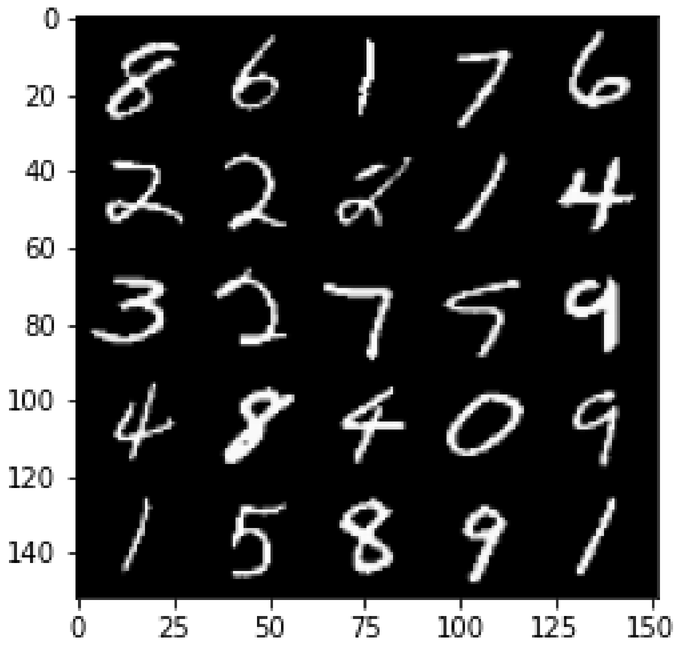
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:54<00:00,  8.68it/s]
 84%|      | 395/469 [00:48<00:08,  8.34it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).

Epoch 45, Step 21500 -> Generator loss: 0.6957097806930534, discriminator loss:
0.6969086651802068
```



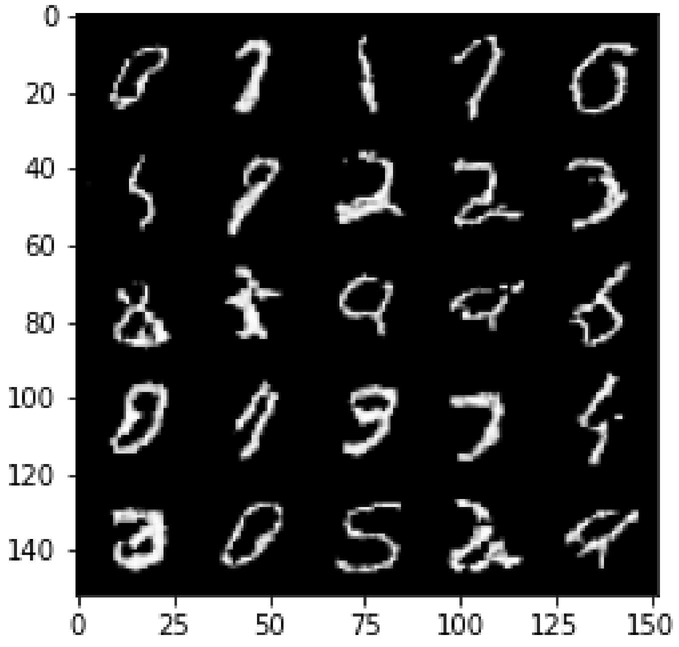
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



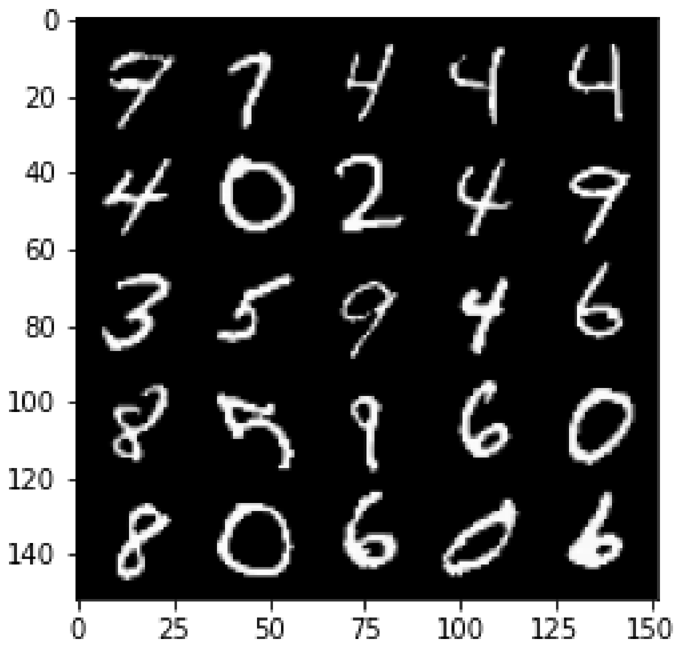
```
100%|      | 469/469 [00:57<00:00,  8.18it/s]
```

```
 91%|      | 426/469 [00:51<00:06,  7.13it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

```
Epoch 46, Step 22000 -> Generator loss: 0.6952036126852036, discriminator loss:
0.6965869933366775
```

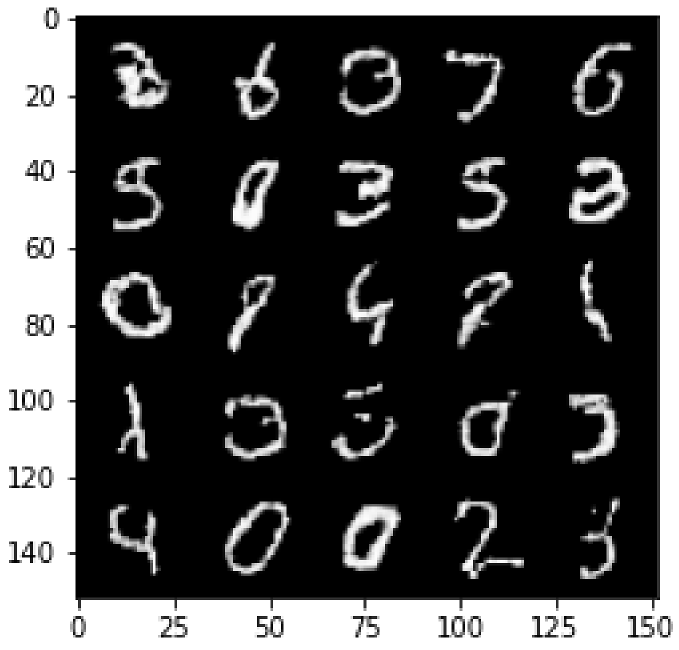


```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

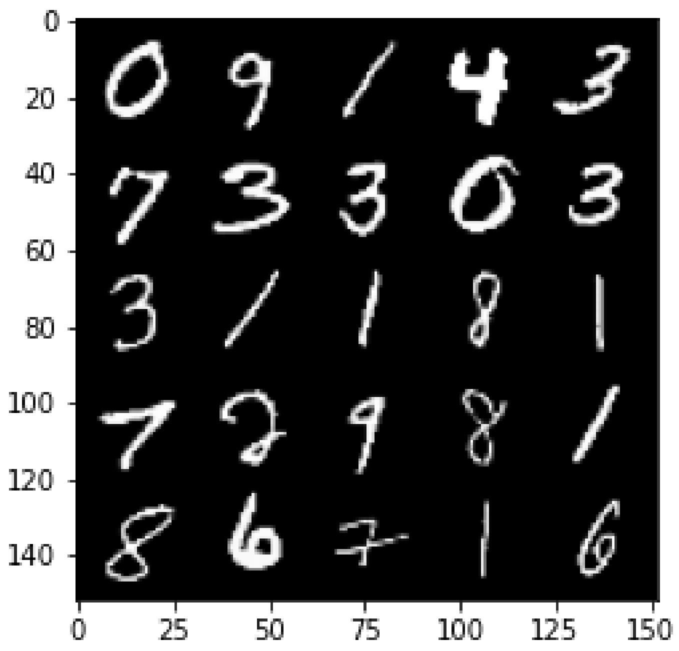


```
100%|          | 469/469 [00:56<00:00,  8.23it/s]
 97%|          | 457/469 [00:52<00:01,  8.87it/s]Clipping input data to the
valid range for imshow with RGB data ([0..1] for floats or [0..255] for
integers).
```

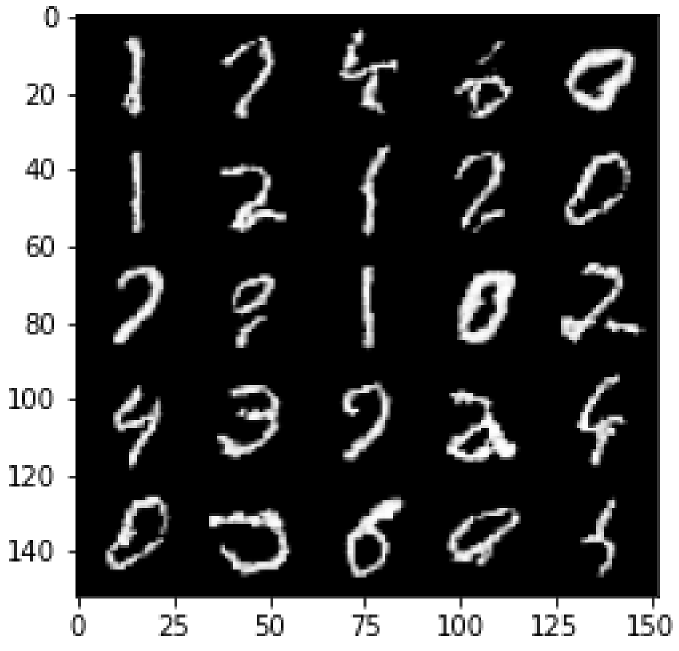
```
Epoch 47, Step 22500 -> Generator loss: 0.6954161245822912, discriminator loss:
0.6965242185592658
```



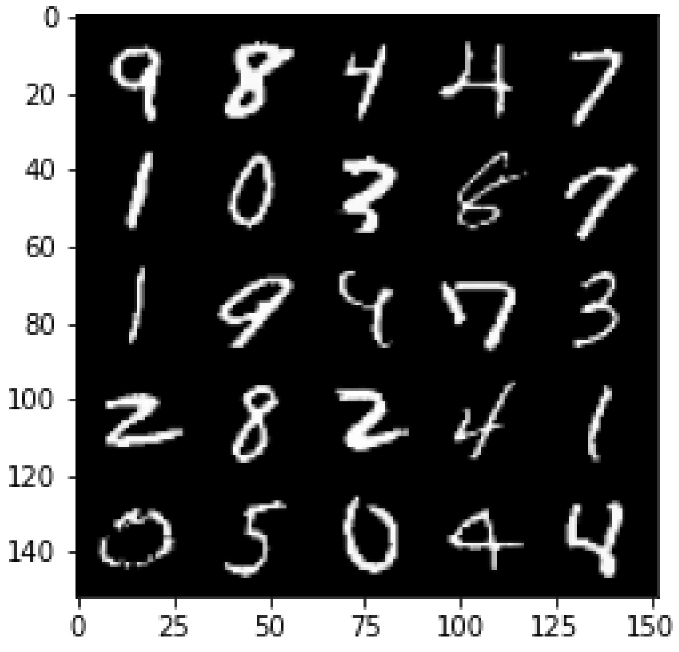
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



```
100%|      | 469/469 [00:53<00:00,  8.69it/s]
100%|      | 469/469 [00:52<00:00,  8.99it/s]
  4%|          | 19/469 [00:02<00:48,  9.22it/s]Clipping input data to the valid
range for imshow with RGB data ([0..1] for floats or [0..255] for integers).

Epoch 49, Step 23000 -> Generator loss: 0.6952557202577596, discriminator loss:
0.6960248352289198
```



```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

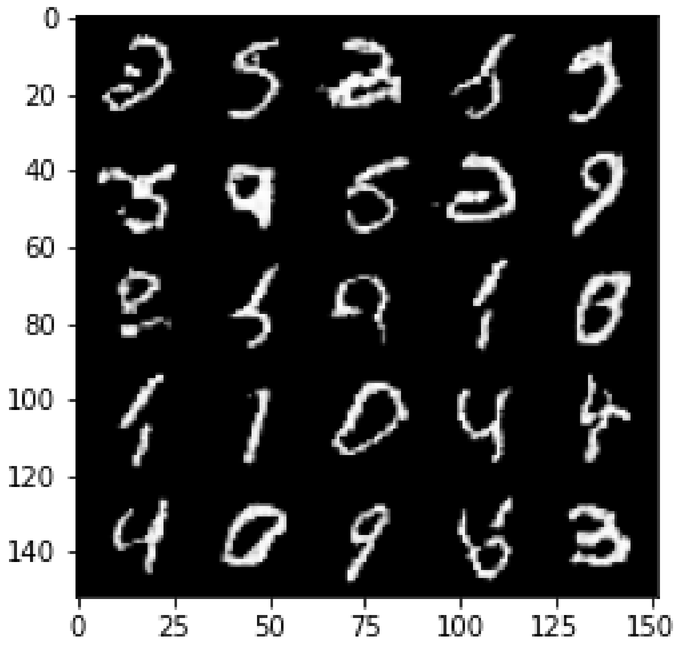


```
100%|      | 469/469 [00:49<00:00,  9.53it/s]
```

```
[ ]: torch.save(gen.state_dict(), 'models/MNIST-DCGAN-Gen-v1.0.pth')
     torch.save(disc.state_dict(), 'models/MNIST-DCGAN-Disc-v1.0.pth')
```

```
[ ]: test_noise = generate_noise(25, 64, device='cuda')
     generated_test = gen(test_noise)
     show_tensor_images(generated_test)
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```



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2 Ramin F. - @SimplyRamin