Lab10_Yunting

November 22, 2021

1 Lab08 - Neural Networks and Deep Learning

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2 Install the required packages

[2]:
```
import os
import numpy as np
import matplotlib.pyplot as plt
from tqdm import tqdm

from tensorflow.keras.layers import Input
from tensorflow.keras.models import Model, Sequential
from tensorflow.keras.layers import Dense, Dropout
from tensorflow.keras.layers import LeakyReLU
from tensorflow.keras.datasets import mnist
from tensorflow.keras.optimizers import Adam
from tensorflow.keras import initializers

# Let Keras know that we are using tensorflow as our backend engine
os.environ["KERAS_BACKEND"] = "tensorflow"
```

3 Exercise 1

This exercise focuses on the original GAN, which is trained on the MNIST database to learn to generate artificial hand-written characters. To implement and train the network, use the TensorFlow framework. You are encouraged to use the Keras high-level API for simplicity.

(a) Load the data set of 60000 to be used for training. Normalize image values so that all values are in the $[1,1]$ interval. In Keras, you may use the functions provided by the `tensorflow.keras.datasets.mnist` module.

[3]:
```
# to make sure we have the same results for each time
np.random.seed(1234)
```

[4]:
```
# load the data
(x_train, y_train), (x_test, y_test) = mnist.load_data()
# normalize the inputs to be in the range[-1, 1]
x_train = (x_train.astype(np.float32) - 127.5) / 127.5
# convert x_train with a shape of (60000, 28, 28) to (60000, 784) so we have␣
 ↪784 columns pre row
x_train = x_train.reshape(60000, 784)
print(x_train.shape)
print(x_test.shape)
print(y_train.shape)
print(y_test.shape)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-
datasets/mnist.npz
11493376/11490434 [==============================] - 0s 0us/step
11501568/11490434 [==============================] - 0s 0us/step
(60000, 784)
(10000, 28, 28)
(60000,)
(10000,)
```

[5]:
```
def load_MINST():
  # load the data
  (x_train, y_train), (x_test, y_test) = mnist.load_data()
  # normalize our inputs to be in the range[-1, 1]
  x_train = (x_train.astype(np.float32) - 127.5)/127.5
  # convert x_train with a shape of (60000, 28, 28) to (60000, 784) so we have
  # 784 columns per row
  x_train = x_train.reshape(60000, 784)
  return (x_train, y_train, x_test, y_test)
```

(b) The generator is fed to its input with a noise vector and outputs an image. The dimension of the input noise vector is 100, and its elements are i.i.d. sampled from a normal distribution of zero mean and unit variance. The generator consists of three fully connected layers with 256, 512, and 1024 neurons, respectively. The activation function used for the neurons in the hidden layers is the leaky ReLU with parameter = 0.2. The output layer comprises 784 nodes and the tanh is employed as the respective activation function.

- Adam is a replacement optimization algorithm for stochastic gradient descent for training deep learning models.

[6]:
```
# The dimension of our random noise vector.
random_dim = 100

# We will use the Adam optimizer
def get_optimizer():
  return Adam(lr = 0.0002, beta_1 = 0.5)
```

[7]:
```
def get_generator(optimizer):
  generator = Sequential()
  # 256 neurons
  generator.add(Dense(256, input_dim=random_dim,kernel_initializer=initializers.
 ↪RandomNormal(stddev=0.02)))
  generator.add(LeakyReLU(0.2))

  # 512 neurons
  generator.add(Dense(512))
  generator.add(LeakyReLU(0.2))

  # 1024 neurons
  generator.add(Dense(1024))
  generator.add(LeakyReLU(0.2))

  generator.add(Dense(784, activation='tanh'))
  generator.compile(loss='binary_crossentropy', optimizer=optimizer)
  return generator
```

(c) The discriminator takes as input a 1 Œ 784 vector, corresponding to the vectorized form of the 28 Œ 28 MNIST images. The discriminator consists of three fully connected layers with 1024, 512, and 256 neurons, respectively. The leaky ReLU activation function is also employed, with $\alpha = 0.2$. During training, use the dropout regularization method, with probability of discarding nodes equal to 0.3. The output layer consist of a single node with a sigmoid activation function.

[8]:
```
def get_discriminator(optimizer):
  discriminator = Sequential()
  discriminator.add(Dense(1024, input_dim=784, kernel_initializer=initializers.
 ↪RandomNormal(stddev=0.02)))
  discriminator.add(LeakyReLU(0.2))
  # use the dropout regularization method, with probability of discarding nodes␣
 ↪equal to 0.3
  discriminator.add(Dropout(0.3))

  discriminator.add(Dense(512))
  discriminator.add(LeakyReLU(0.2))
  discriminator.add(Dropout(0.3))

  discriminator.add(Dense(256))
  discriminator.add(LeakyReLU(0.2))
  discriminator.add(Dropout(0.3))

  discriminator.add(Dense(1, activation='sigmoid'))
  discriminator.compile(loss='binary_crossentropy', optimizer=optimizer)
  return discriminator
```

(d) To train the implemented network, use the two-class (binary) cross-entropy loss function. Adopt the Adam minimizer with step size (learning rate) equal to 210^3 , $\beta 1 = 0.5$, and $\beta 2 = 0.999$ as parameters for the optimizer. The recommended batch size is 100. Train the network for 400 epochs as follows. For each training loop, (a) generate a random set of input noise and images, (b) generate fake images via the generator, (c) train only the discriminator, and (d) then train only the generator, according to Algorithm 18.5. Play with the number of iterations, associated with the discriminator training.

[9]:
```
def get_gan_network(discriminator, random_dim, generator, optimizer):
  # We initially set trainable to False since we only want to train either the␣
 ↪generator or discriminator at a time
  discriminator.trainable = False

  # gan input (noise) will be 100-dimensional vectors
  gan_input = Input(shape=(random_dim,))

  # the output of the generator (an image)
  x = generator(gan_input)
  # get the output of the discriminator (probability if the image is real or␣
 ↪not)
  gan_output = discriminator(x)
  gan = Model(inputs=gan_input, outputs=gan_output)
  gan.compile(loss='binary_crossentropy', optimizer=optimizer)
  return gan
```

[10]:
```
def plot_generated_images(epoch, generator, examples=100, dim=(10, 10),␣
 ↪figsize=(10, 10)):
  noise = np.random.normal(0, 1, size=[examples, random_dim])
  generated_images = generator.predict(noise)
  generated_images = generated_images.reshape(examples, 28, 28)
  plt.figure(figsize=figsize)
  for i in range(generated_images.shape[0]):
    plt.subplot(dim[0], dim[1], i+1)
    plt.imshow(generated_images[i], interpolation='nearest', cmap='gray_r')
    plt.axis('off')
    plt.tight_layout()
  %cd /content/drive/MyDrive/American_University/2021_Fall/
 ↪DATA-642-001_Advanced Machine Learning/GitHub/Labs/10/submit
  plt.savefig('gan_generated_image_epoch_%d.png' % epoch)
```

(e) During training and every 20 epochs, visualize the generated images created by the generator and comment on the evolution of the learning process.

[11]:
```
def train(epochs=1, batch_size=128):
  # Get the training and testing data
  x_train, y_train, x_test, y_test = load_MINST()
  # Split the training data into batches of size 128
  batch_count = x_train.shape[0] / batch_size
```

```
# Build the GAN netowrk
adam = get_optimizer()
generator = get_generator(adam)
discriminator = get_discriminator(adam)
gan = get_gan_network(discriminator, random_dim, generator, adam)
for e in range(1, epochs+1):
  print('-'*15, 'Epoch %d' % e, '-'*15)
  for _ in tqdm(range(0, int(batch_count))):
    # Get a random set of input noise and images
    noise = np.random.normal(0, 1, size=[batch_size, random_dim])
    image_batch = x_train[np.random.randint(0, x_train.shape[0],␣
↪size=batch_size)]
    # Generate fake MNIST images
    generated_images = generator.predict(noise)
    X = np.concatenate([image_batch, generated_images])
    # Labels for generated and real data
    y_dis = np.zeros(2*batch_size)
    # One-sided label smoothing
    y_dis[:batch_size] = 0.9
    3
    # Train discriminator
    discriminator.trainable = True
    discriminator.train_on_batch(X, y_dis)
    # Train generat or
    noise = np.random.normal(0, 1, size=[batch_size, random_dim])
    y_gen = np.ones(batch_size)
    discriminator.trainable = False
    gan.train_on_batch(noise, y_gen)
  if e == 1 or e % 20 == 0:
    plot_generated_images(e, generator)
```

(f) Play with all the various parameters that have been suggested above and see the effect on the training.

- According to the question, the recommended batch size is 100. Train the network for 400 epochs as follows.
- Iterations is the number of batches needed to complete one epoch. Note: The number of batches is equal to number of iterations for one epoch. We can divide the dataset of 2000 examples into batches of 500 then it will take 4 iterations to complete 1 epoch.
- We can see if the higher the epoch number, the clearer the image output. After epoch 180, We can easily distinguish digit numbers from our eyes.
- iteration= (total observation/batch_size). That is, 60000/100 = 600 iterations to complete 1 epoch.

[ ]:
```
if __name__ == '__main__':
  train(epochs=400, batch_size=100)
```

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/adam.py:105:
UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.
  super(Adam, self).__init__(name, **kwargs)

--------------- Epoch 1 ---------------

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--------------- Epoch 2 ---------------

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--------------- Epoch 3 ---------------

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--------------- Epoch 4 ---------------

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--------------- Epoch 5 ---------------

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--------------- Epoch 6 ---------------

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--------------- Epoch 7 ---------------

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--------------- Epoch 8 ---------------

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--------------- Epoch 9 ---------------

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--------------- Epoch 10 ---------------

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--------------- Epoch 11 ---------------

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--------------- Epoch 12 ---------------
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--------------- Epoch 13 ---------------

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--------------- Epoch 14 ---------------

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--------------- Epoch 15 ---------------

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--------------- Epoch 16 ---------------

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--------------- Epoch 17 ---------------

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--------------- Epoch 18 ---------------

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--------------- Epoch 19 ---------------

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--------------- Epoch 20 ---------------

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--------------- Epoch 21 ---------------

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--------------- Epoch 22 ---------------

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--------------- Epoch 23 ---------------

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--------------- Epoch 24 ---------------

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```
--------------- Epoch 25 ---------------
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--------------- Epoch 35 ---------------
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--------------- Epoch 36 ---------------
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--------------- Epoch 37 ---------------
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--------------- Epoch 38 ---------------
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--------------- Epoch 40 ---------------

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--------------- Epoch 43 ---------------

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--------------- Epoch 60 ---------------

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--------------- Epoch 62 ---------------

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--------------- Epoch 63 ---------------
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--------------- Epoch 100 ---------------

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--------------- Epoch 140 ---------------
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--------------- Epoch 141 ---------------

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--------------- Epoch 142 ---------------

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--------------- Epoch 143 ---------------

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--------------- Epoch 144 ---------------

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--------------- Epoch 145 ---------------

100%|| 600/600 [01:34<00:00,  6.33it/s]

--------------- Epoch 146 ---------------

100%|| 600/600 [01:34<00:00,  6.37it/s]

--------------- Epoch 147 ---------------

100%|| 600/600 [01:35<00:00,  6.28it/s]

--------------- Epoch 148 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 149 ---------------

100%|| 600/600 [01:34<00:00,  6.37it/s]

--------------- Epoch 150 ---------------

100%|| 600/600 [01:33<00:00,  6.41it/s]

--------------- Epoch 151 ---------------

100%|| 600/600 [01:33<00:00,  6.42it/s]

--------------- Epoch 152 ---------------

100%|| 600/600 [01:35<00:00,  6.26it/s]

--------------- Epoch 153 ---------------
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100%|| 600/600 [01:34<00:00,  6.32it/s]

--------------- Epoch 154 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 155 ---------------

100%|| 600/600 [01:33<00:00,  6.38it/s]

--------------- Epoch 156 ---------------

100%|| 600/600 [01:33<00:00,  6.40it/s]

--------------- Epoch 157 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 158 ---------------

100%|| 600/600 [01:34<00:00,  6.35it/s]

--------------- Epoch 159 ---------------

100%|| 600/600 [01:35<00:00,  6.26it/s]

--------------- Epoch 160 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]

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--------------- Epoch 161 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 162 ---------------

100%|| 600/600 [01:35<00:00,  6.25it/s]

--------------- Epoch 163 ---------------

100%|| 600/600 [01:36<00:00,  6.24it/s]

--------------- Epoch 164 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 165 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]
```

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--------------- Epoch 166 ---------------
100%|| 600/600 [01:35<00:00,  6.30it/s]
--------------- Epoch 167 ---------------
100%|| 600/600 [01:34<00:00,  6.33it/s]
--------------- Epoch 168 ---------------
100%|| 600/600 [01:34<00:00,  6.34it/s]
--------------- Epoch 169 ---------------
100%|| 600/600 [01:34<00:00,  6.35it/s]
--------------- Epoch 170 ---------------
100%|| 600/600 [01:34<00:00,  6.36it/s]
--------------- Epoch 171 ---------------
100%|| 600/600 [01:36<00:00,  6.24it/s]
--------------- Epoch 172 ---------------
100%|| 600/600 [01:35<00:00,  6.29it/s]
--------------- Epoch 173 ---------------
100%|| 600/600 [01:35<00:00,  6.27it/s]
--------------- Epoch 174 ---------------
100%|| 600/600 [01:35<00:00,  6.26it/s]
--------------- Epoch 175 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 176 ---------------
100%|| 600/600 [01:37<00:00,  6.13it/s]
--------------- Epoch 177 ---------------
100%|| 600/600 [01:37<00:00,  6.17it/s]
--------------- Epoch 178 ---------------
100%|| 600/600 [01:38<00:00,  6.09it/s]
--------------- Epoch 179 ---------------
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```
100%|| 600/600 [01:38<00:00,  6.10it/s]

--------------- Epoch 180 ---------------

100%|| 600/600 [01:37<00:00,  6.15it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 181 ---------------

100%|| 600/600 [01:37<00:00,  6.18it/s]

--------------- Epoch 182 ---------------

100%|| 600/600 [01:37<00:00,  6.13it/s]

--------------- Epoch 183 ---------------

100%|| 600/600 [01:37<00:00,  6.15it/s]

--------------- Epoch 184 ---------------

100%|| 600/600 [01:36<00:00,  6.20it/s]

--------------- Epoch 185 ---------------

100%|| 600/600 [01:37<00:00,  6.17it/s]

--------------- Epoch 186 ---------------

100%|| 600/600 [01:38<00:00,  6.10it/s]

--------------- Epoch 187 ---------------

100%|| 600/600 [01:38<00:00,  6.09it/s]

--------------- Epoch 188 ---------------

100%|| 600/600 [01:37<00:00,  6.14it/s]

--------------- Epoch 189 ---------------

100%|| 600/600 [01:37<00:00,  6.14it/s]

--------------- Epoch 190 ---------------

100%|| 600/600 [01:37<00:00,  6.14it/s]

--------------- Epoch 191 ---------------

100%|| 600/600 [01:39<00:00,  6.03it/s]
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--------------- Epoch 192 ---------------

100%|| 600/600 [01:37<00:00,  6.14it/s]

--------------- Epoch 193 ---------------

100%|| 600/600 [01:40<00:00,  5.98it/s]

--------------- Epoch 194 ---------------

100%|| 600/600 [01:38<00:00,  6.12it/s]

--------------- Epoch 195 ---------------

100%|| 600/600 [01:38<00:00,  6.09it/s]

--------------- Epoch 196 ---------------

100%|| 600/600 [01:39<00:00,  6.05it/s]

--------------- Epoch 197 ---------------

100%|| 600/600 [01:39<00:00,  6.00it/s]

--------------- Epoch 198 ---------------

100%|| 600/600 [01:38<00:00,  6.09it/s]

--------------- Epoch 199 ---------------

100%|| 600/600 [01:39<00:00,  6.01it/s]

--------------- Epoch 200 ---------------

100%|| 600/600 [01:40<00:00,  5.99it/s]

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--------------- Epoch 201 ---------------

100%|| 600/600 [01:42<00:00,  5.85it/s]

--------------- Epoch 202 ---------------

100%|| 600/600 [01:40<00:00,  5.97it/s]

--------------- Epoch 203 ---------------

100%|| 600/600 [01:39<00:00,  6.04it/s]

--------------- Epoch 204 ---------------
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100%|| 600/600 [01:39<00:00,  6.02it/s]
--------------- Epoch 205 ---------------
100%|| 600/600 [01:39<00:00,  6.06it/s]
--------------- Epoch 206 ---------------
100%|| 600/600 [01:38<00:00,  6.11it/s]
--------------- Epoch 207 ---------------
100%|| 600/600 [01:37<00:00,  6.18it/s]
--------------- Epoch 208 ---------------
100%|| 600/600 [01:37<00:00,  6.19it/s]
--------------- Epoch 209 ---------------
100%|| 600/600 [01:36<00:00,  6.19it/s]
--------------- Epoch 210 ---------------
100%|| 600/600 [01:37<00:00,  6.17it/s]
--------------- Epoch 211 ---------------
100%|| 600/600 [01:38<00:00,  6.11it/s]
--------------- Epoch 212 ---------------
100%|| 600/600 [01:37<00:00,  6.14it/s]
--------------- Epoch 213 ---------------
100%|| 600/600 [01:37<00:00,  6.14it/s]
--------------- Epoch 214 ---------------
100%|| 600/600 [01:39<00:00,  6.04it/s]
--------------- Epoch 215 ---------------
100%|| 600/600 [01:37<00:00,  6.12it/s]
--------------- Epoch 216 ---------------
100%|| 600/600 [01:37<00:00,  6.14it/s]
--------------- Epoch 217 ---------------
100%|| 600/600 [01:36<00:00,  6.21it/s]
```

```
--------------- Epoch 218 ---------------

100%|| 600/600 [01:36<00:00,  6.23it/s]

--------------- Epoch 219 ---------------

100%|| 600/600 [01:36<00:00,  6.22it/s]

--------------- Epoch 220 ---------------

100%|| 600/600 [01:38<00:00,  6.11it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 221 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 222 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 223 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 224 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 225 ---------------

100%|| 600/600 [01:35<00:00,  6.26it/s]

--------------- Epoch 226 ---------------

100%|| 600/600 [01:34<00:00,  6.33it/s]

--------------- Epoch 227 ---------------

100%|| 600/600 [01:33<00:00,  6.40it/s]

--------------- Epoch 228 ---------------

100%|| 600/600 [01:34<00:00,  6.37it/s]

--------------- Epoch 229 ---------------

100%|| 600/600 [01:35<00:00,  6.31it/s]

--------------- Epoch 230 ---------------
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```
100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 231 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 232 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 233 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 234 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 235 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 236 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 237 ---------------

100%|| 600/600 [01:34<00:00,  6.32it/s]

--------------- Epoch 238 ---------------

100%|| 600/600 [01:37<00:00,  6.17it/s]

--------------- Epoch 239 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 240 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 241 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]

--------------- Epoch 242 ---------------

100%|| 600/600 [01:36<00:00,  6.24it/s]
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--------------- Epoch 243 ---------------
100%|| 600/600 [01:38<00:00,  6.11it/s]
--------------- Epoch 244 ---------------
100%|| 600/600 [01:34<00:00,  6.33it/s]
--------------- Epoch 245 ---------------
100%|| 600/600 [01:33<00:00,  6.40it/s]
--------------- Epoch 246 ---------------
100%|| 600/600 [01:33<00:00,  6.39it/s]
--------------- Epoch 247 ---------------
100%|| 600/600 [01:34<00:00,  6.36it/s]
--------------- Epoch 248 ---------------
100%|| 600/600 [01:34<00:00,  6.37it/s]
--------------- Epoch 249 ---------------
100%|| 600/600 [01:34<00:00,  6.37it/s]
--------------- Epoch 250 ---------------
100%|| 600/600 [01:36<00:00,  6.20it/s]
--------------- Epoch 251 ---------------
100%|| 600/600 [01:35<00:00,  6.28it/s]
--------------- Epoch 252 ---------------
100%|| 600/600 [01:36<00:00,  6.24it/s]
--------------- Epoch 253 ---------------
100%|| 600/600 [01:35<00:00,  6.30it/s]
--------------- Epoch 254 ---------------
100%|| 600/600 [01:35<00:00,  6.30it/s]
--------------- Epoch 255 ---------------
100%|| 600/600 [01:35<00:00,  6.30it/s]
--------------- Epoch 256 ---------------
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100%|| 600/600 [01:34<00:00,  6.35it/s]

--------------- Epoch 257 ---------------

100%|| 600/600 [01:35<00:00,  6.25it/s]

--------------- Epoch 258 ---------------

100%|| 600/600 [01:34<00:00,  6.33it/s]

--------------- Epoch 259 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 260 ---------------

100%|| 600/600 [01:33<00:00,  6.38it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 261 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 262 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 263 ---------------

100%|| 600/600 [01:35<00:00,  6.26it/s]

--------------- Epoch 264 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 265 ---------------

100%|| 600/600 [01:36<00:00,  6.21it/s]

--------------- Epoch 266 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 267 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]

--------------- Epoch 268 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]
```

```
--------------- Epoch 269 ---------------

100%|| 600/600 [01:34<00:00,  6.32it/s]

--------------- Epoch 270 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 271 ---------------

100%|| 600/600 [01:34<00:00,  6.38it/s]

--------------- Epoch 272 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 273 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 274 ---------------

100%|| 600/600 [01:34<00:00,  6.35it/s]

--------------- Epoch 275 ---------------

100%|| 600/600 [01:34<00:00,  6.34it/s]

--------------- Epoch 276 ---------------

100%|| 600/600 [01:34<00:00,  6.36it/s]

--------------- Epoch 277 ---------------

100%|| 600/600 [01:34<00:00,  6.34it/s]

--------------- Epoch 278 ---------------

100%|| 600/600 [01:37<00:00,  6.19it/s]

--------------- Epoch 279 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 280 ---------------

100%|| 600/600 [01:36<00:00,  6.21it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 281 ---------------
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```
100%|| 600/600 [01:37<00:00,  6.17it/s]
--------------- Epoch 282 ---------------
100%|| 600/600 [01:36<00:00,  6.21it/s]
--------------- Epoch 283 ---------------
100%|| 600/600 [01:39<00:00,  6.05it/s]
--------------- Epoch 284 ---------------
100%|| 600/600 [01:36<00:00,  6.21it/s]
--------------- Epoch 285 ---------------
100%|| 600/600 [01:36<00:00,  6.21it/s]
--------------- Epoch 286 ---------------
100%|| 600/600 [01:36<00:00,  6.25it/s]
--------------- Epoch 287 ---------------
100%|| 600/600 [01:35<00:00,  6.25it/s]
--------------- Epoch 288 ---------------
100%|| 600/600 [01:35<00:00,  6.28it/s]
--------------- Epoch 289 ---------------
100%|| 600/600 [01:35<00:00,  6.26it/s]
--------------- Epoch 290 ---------------
100%|| 600/600 [01:36<00:00,  6.25it/s]
--------------- Epoch 291 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 292 ---------------
100%|| 600/600 [01:40<00:00,  5.98it/s]
--------------- Epoch 293 ---------------
100%|| 600/600 [01:35<00:00,  6.27it/s]
--------------- Epoch 294 ---------------
100%|| 600/600 [01:35<00:00,  6.31it/s]
```

```
--------------- Epoch 295 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 296 ---------------

100%|| 600/600 [01:35<00:00,  6.28it/s]

--------------- Epoch 297 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]

--------------- Epoch 298 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 299 ---------------

100%|| 600/600 [01:34<00:00,  6.34it/s]

--------------- Epoch 300 ---------------

100%|| 600/600 [01:38<00:00,  6.11it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 301 ---------------

100%|| 600/600 [01:35<00:00,  6.30it/s]

--------------- Epoch 302 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 303 ---------------

100%|| 600/600 [01:35<00:00,  6.26it/s]

--------------- Epoch 304 ---------------

100%|| 600/600 [01:36<00:00,  6.25it/s]

--------------- Epoch 305 ---------------

100%|| 600/600 [01:36<00:00,  6.22it/s]

--------------- Epoch 306 ---------------

100%|| 600/600 [01:38<00:00,  6.08it/s]

--------------- Epoch 307 ---------------
```

```
100%|| 600/600 [01:39<00:00,  6.02it/s]
--------------- Epoch 308 ---------------
100%|| 600/600 [01:38<00:00,  6.08it/s]
--------------- Epoch 309 ---------------
100%|| 600/600 [01:37<00:00,  6.13it/s]
--------------- Epoch 310 ---------------
100%|| 600/600 [01:37<00:00,  6.15it/s]
--------------- Epoch 311 ---------------
100%|| 600/600 [01:37<00:00,  6.19it/s]
--------------- Epoch 312 ---------------
100%|| 600/600 [01:36<00:00,  6.20it/s]
--------------- Epoch 313 ---------------
100%|| 600/600 [01:36<00:00,  6.22it/s]
--------------- Epoch 314 ---------------
100%|| 600/600 [01:36<00:00,  6.20it/s]
--------------- Epoch 315 ---------------
100%|| 600/600 [01:37<00:00,  6.14it/s]
--------------- Epoch 316 ---------------
100%|| 600/600 [01:35<00:00,  6.31it/s]
--------------- Epoch 317 ---------------
100%|| 600/600 [01:35<00:00,  6.28it/s]
--------------- Epoch 318 ---------------
100%|| 600/600 [01:35<00:00,  6.29it/s]
--------------- Epoch 319 ---------------
100%|| 600/600 [01:35<00:00,  6.30it/s]
--------------- Epoch 320 ---------------
100%|| 600/600 [01:35<00:00,  6.26it/s]
```

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/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 321 ---------------

100%|| 600/600 [01:37<00:00,  6.15it/s]

--------------- Epoch 322 ---------------

100%|| 600/600 [01:41<00:00,  5.92it/s]

--------------- Epoch 323 ---------------

100%|| 600/600 [01:37<00:00,  6.13it/s]

--------------- Epoch 324 ---------------

100%|| 600/600 [01:37<00:00,  6.13it/s]

--------------- Epoch 325 ---------------

100%|| 600/600 [01:37<00:00,  6.15it/s]

--------------- Epoch 326 ---------------

100%|| 600/600 [01:37<00:00,  6.18it/s]

--------------- Epoch 327 ---------------

100%|| 600/600 [01:38<00:00,  6.12it/s]

--------------- Epoch 328 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 329 ---------------

100%|| 600/600 [01:36<00:00,  6.20it/s]

--------------- Epoch 330 ---------------

100%|| 600/600 [01:36<00:00,  6.22it/s]

--------------- Epoch 331 ---------------

100%|| 600/600 [01:40<00:00,  5.99it/s]

--------------- Epoch 332 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 333 ---------------
```

```
100%|| 600/600 [01:36<00:00,  6.20it/s]

--------------- Epoch 334 ---------------

100%|| 600/600 [01:36<00:00,  6.19it/s]

--------------- Epoch 335 ---------------

100%|| 600/600 [01:36<00:00,  6.21it/s]

--------------- Epoch 336 ---------------

100%|| 600/600 [01:36<00:00,  6.23it/s]

--------------- Epoch 337 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 338 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 339 ---------------

100%|| 600/600 [01:37<00:00,  6.18it/s]

--------------- Epoch 340 ---------------

100%|| 600/600 [01:39<00:00,  6.03it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 341 ---------------

100%|| 600/600 [01:35<00:00,  6.29it/s]

--------------- Epoch 342 ---------------

100%|| 600/600 [01:35<00:00,  6.27it/s]

--------------- Epoch 343 ---------------

100%|| 600/600 [01:36<00:00,  6.25it/s]

--------------- Epoch 344 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 345 ---------------

100%|| 600/600 [01:37<00:00,  6.18it/s]
```

```
--------------- Epoch 346 ---------------
100%|| 600/600 [01:36<00:00,  6.20it/s]
--------------- Epoch 347 ---------------
100%|| 600/600 [01:39<00:00,  6.01it/s]
--------------- Epoch 348 ---------------
100%|| 600/600 [01:36<00:00,  6.22it/s]
--------------- Epoch 349 ---------------
100%|| 600/600 [01:35<00:00,  6.27it/s]
--------------- Epoch 350 ---------------
100%|| 600/600 [01:35<00:00,  6.25it/s]
--------------- Epoch 351 ---------------
100%|| 600/600 [01:36<00:00,  6.24it/s]
--------------- Epoch 352 ---------------
100%|| 600/600 [01:35<00:00,  6.26it/s]
--------------- Epoch 353 ---------------
100%|| 600/600 [01:35<00:00,  6.29it/s]
--------------- Epoch 354 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 355 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 356 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 357 ---------------
100%|| 600/600 [01:40<00:00,  5.95it/s]
--------------- Epoch 358 ---------------
100%|| 600/600 [01:38<00:00,  6.10it/s]
--------------- Epoch 359 ---------------
```

```
100%|| 600/600 [01:37<00:00,  6.15it/s]

--------------- Epoch 360 ---------------

100%|| 600/600 [01:37<00:00,  6.17it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 361 ---------------

100%|| 600/600 [01:37<00:00,  6.15it/s]

--------------- Epoch 362 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 363 ---------------

100%|| 600/600 [01:37<00:00,  6.17it/s]

--------------- Epoch 364 ---------------

100%|| 600/600 [01:41<00:00,  5.94it/s]

--------------- Epoch 365 ---------------

100%|| 600/600 [01:38<00:00,  6.09it/s]

--------------- Epoch 366 ---------------

100%|| 600/600 [01:38<00:00,  6.08it/s]

--------------- Epoch 367 ---------------

100%|| 600/600 [01:39<00:00,  6.03it/s]

--------------- Epoch 368 ---------------

100%|| 600/600 [01:38<00:00,  6.07it/s]

--------------- Epoch 369 ---------------

100%|| 600/600 [01:39<00:00,  6.04it/s]

--------------- Epoch 370 ---------------

100%|| 600/600 [01:39<00:00,  6.00it/s]

--------------- Epoch 371 ---------------

100%|| 600/600 [01:39<00:00,  6.03it/s]
```

```
--------------- Epoch 372 ---------------

100%|| 600/600 [01:39<00:00,  6.04it/s]

--------------- Epoch 373 ---------------

100%|| 600/600 [01:39<00:00,  6.01it/s]

--------------- Epoch 374 ---------------

100%|| 600/600 [01:39<00:00,  6.04it/s]

--------------- Epoch 375 ---------------

100%|| 600/600 [01:41<00:00,  5.88it/s]

--------------- Epoch 376 ---------------

100%|| 600/600 [01:38<00:00,  6.10it/s]

--------------- Epoch 377 ---------------

100%|| 600/600 [01:39<00:00,  6.05it/s]

--------------- Epoch 378 ---------------

100%|| 600/600 [01:38<00:00,  6.10it/s]

--------------- Epoch 379 ---------------

100%|| 600/600 [01:38<00:00,  6.10it/s]

--------------- Epoch 380 ---------------

100%|| 600/600 [01:37<00:00,  6.14it/s]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 381 ---------------

100%|| 600/600 [01:36<00:00,  6.22it/s]

--------------- Epoch 382 ---------------

100%|| 600/600 [01:36<00:00,  6.20it/s]

--------------- Epoch 383 ---------------

100%|| 600/600 [01:40<00:00,  6.00it/s]

--------------- Epoch 384 ---------------
```
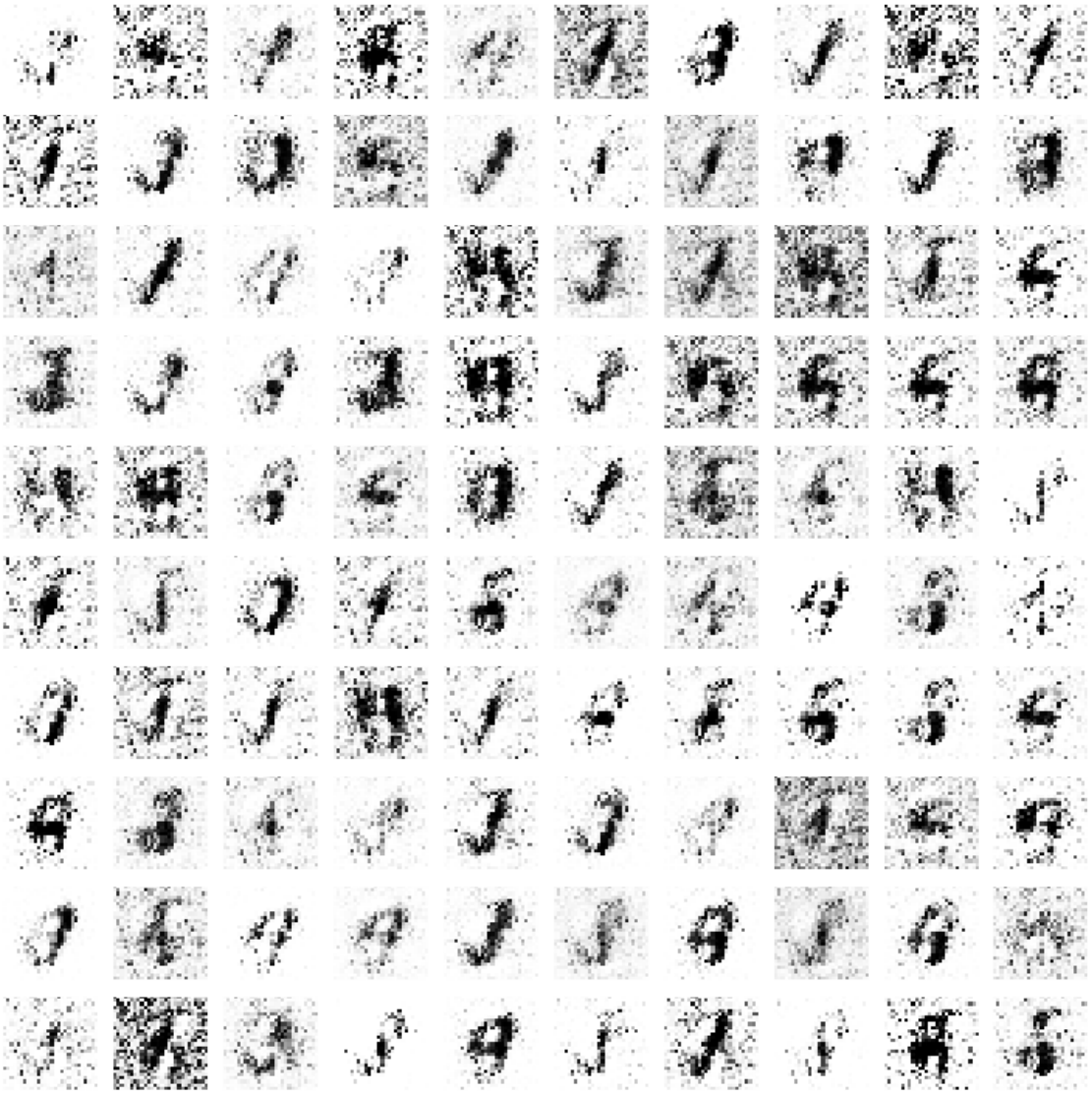
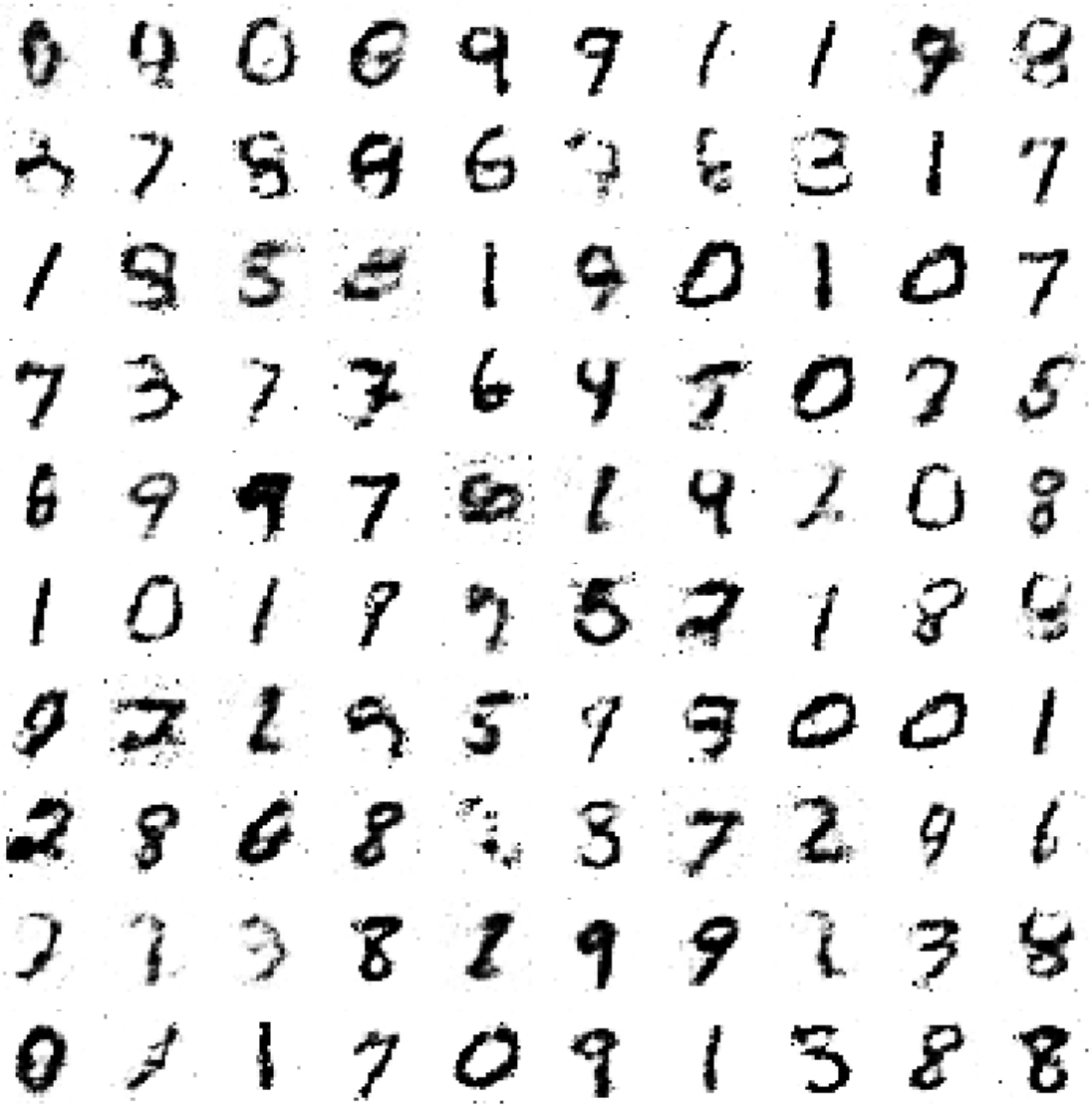

```
100%|| 600/600 [01:37<00:00,  6.17it/s]
--------------- Epoch 385 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 386 ---------------
100%|| 600/600 [01:35<00:00,  6.27it/s]
--------------- Epoch 387 ---------------
100%|| 600/600 [01:36<00:00,  6.25it/s]
--------------- Epoch 388 ---------------
100%|| 600/600 [01:35<00:00,  6.28it/s]
--------------- Epoch 389 ---------------
100%|| 600/600 [01:35<00:00,  6.25it/s]
--------------- Epoch 390 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 391 ---------------
100%|| 600/600 [01:36<00:00,  6.22it/s]
--------------- Epoch 392 ---------------
100%|| 600/600 [01:36<00:00,  6.23it/s]
--------------- Epoch 393 ---------------
100%|| 600/600 [01:40<00:00,  5.96it/s]
--------------- Epoch 394 ---------------
100%|| 600/600 [01:38<00:00,  6.11it/s]
--------------- Epoch 395 ---------------
100%|| 600/600 [01:37<00:00,  6.13it/s]
--------------- Epoch 396 ---------------
100%|| 600/600 [01:36<00:00,  6.21it/s]
--------------- Epoch 397 ---------------
100%|| 600/600 [01:36<00:00,  6.19it/s]
```

```
--------------- Epoch 398 ---------------

100%|| 600/600 [01:37<00:00,  6.13it/s]

--------------- Epoch 399 ---------------

100%|| 600/600 [01:37<00:00,  6.16it/s]

--------------- Epoch 400 ---------------

100%|| 600/600 [01:36<00:00,  6.21it/s]
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:5: RuntimeWarning:
More than 20 figures have been opened. Figures created through the pyplot
interface (`matplotlib.pyplot.figure`) are retained until explicitly closed and
may consume too much memory. (To control this warning, see the rcParam
`figure.max_open_warning`).
  """

/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
```





We have 60000 observations. We should try to increase the number of iteration in order to get better results. However, in order to save the computation time, I will should the bad result below.

[12]:
```
x_train.shape[0]
```

[12]:
```
60000
```

- iteration = (total observation/batch_size). That is, 60000/10000 = 6 iterations to complete 1 epoch.
- We can see the example below, if the number of batch size is big, the model cannot be trained well. In this example, the model only have six iterations in every single epoch.
- Ideally, batch size of 32, 64, 128, 256 are good start points.

[16]:
```
if __name__ == '__main__':
  train(epochs=100, batch_size=10000)
```

```
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/adam.py:105:
UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.
  super(Adam, self).__init__(name, **kwargs)

--------------- Epoch 1 ---------------

100%|| 6/6 [00:39<00:00,  6.54s/it]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 2 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 3 ---------------

100%|| 6/6 [00:37<00:00,  6.31s/it]

--------------- Epoch 4 ---------------

100%|| 6/6 [00:37<00:00,  6.22s/it]

--------------- Epoch 5 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 6 ---------------

100%|| 6/6 [00:37<00:00,  6.20s/it]

--------------- Epoch 7 ---------------

100%|| 6/6 [00:38<00:00,  6.34s/it]

--------------- Epoch 8 ---------------

100%|| 6/6 [00:37<00:00,  6.31s/it]

--------------- Epoch 9 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 10 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 11 ---------------
```

```
100%|| 6/6 [00:37<00:00,  6.25s/it]

--------------- Epoch 12 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 13 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 14 ---------------

100%|| 6/6 [00:37<00:00,  6.33s/it]

--------------- Epoch 15 ---------------

100%|| 6/6 [00:37<00:00,  6.26s/it]

--------------- Epoch 16 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 17 ---------------

100%|| 6/6 [00:37<00:00,  6.30s/it]

--------------- Epoch 18 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 19 ---------------

100%|| 6/6 [00:37<00:00,  6.21s/it]

--------------- Epoch 20 ---------------

100%|| 6/6 [00:37<00:00,  6.25s/it]

/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 21 ---------------

100%|| 6/6 [00:37<00:00,  6.24s/it]

--------------- Epoch 22 ---------------

100%|| 6/6 [00:37<00:00,  6.25s/it]

--------------- Epoch 23 ---------------

100%|| 6/6 [00:38<00:00,  6.34s/it]
```

```
--------------- Epoch 24 ---------------
100%|| 6/6 [00:37<00:00,  6.27s/it]
--------------- Epoch 25 ---------------
100%|| 6/6 [00:37<00:00,  6.25s/it]
--------------- Epoch 26 ---------------
100%|| 6/6 [00:37<00:00,  6.29s/it]
--------------- Epoch 27 ---------------
100%|| 6/6 [00:37<00:00,  6.30s/it]
--------------- Epoch 28 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 29 ---------------
100%|| 6/6 [00:37<00:00,  6.28s/it]
--------------- Epoch 30 ---------------
100%|| 6/6 [00:37<00:00,  6.25s/it]
--------------- Epoch 31 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 32 ---------------
100%|| 6/6 [00:37<00:00,  6.24s/it]
--------------- Epoch 33 ---------------
100%|| 6/6 [00:37<00:00,  6.27s/it]
--------------- Epoch 34 ---------------
100%|| 6/6 [00:37<00:00,  6.26s/it]
--------------- Epoch 35 ---------------
100%|| 6/6 [00:37<00:00,  6.31s/it]
--------------- Epoch 36 ---------------
100%|| 6/6 [00:37<00:00,  6.23s/it]
--------------- Epoch 37 ---------------
```

```
100%|| 6/6 [00:37<00:00,  6.22s/it]

--------------- Epoch 38 ---------------

100%|| 6/6 [00:37<00:00,  6.20s/it]

--------------- Epoch 39 ---------------

100%|| 6/6 [00:37<00:00,  6.19s/it]

--------------- Epoch 40 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 41 ---------------

100%|| 6/6 [00:37<00:00,  6.24s/it]

--------------- Epoch 42 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 43 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 44 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 45 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 46 ---------------

100%|| 6/6 [00:37<00:00,  6.25s/it]

--------------- Epoch 47 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 48 ---------------

100%|| 6/6 [00:37<00:00,  6.21s/it]

--------------- Epoch 49 ---------------

100%|| 6/6 [00:37<00:00,  6.21s/it]
```

```
--------------- Epoch 50 ---------------

100%|| 6/6 [00:37<00:00,  6.30s/it]

--------------- Epoch 51 ---------------

100%|| 6/6 [00:36<00:00,  6.14s/it]

--------------- Epoch 52 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 53 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 54 ---------------

100%|| 6/6 [00:37<00:00,  6.19s/it]

--------------- Epoch 55 ---------------

100%|| 6/6 [00:37<00:00,  6.30s/it]

--------------- Epoch 56 ---------------

100%|| 6/6 [00:37<00:00,  6.23s/it]

--------------- Epoch 57 ---------------

100%|| 6/6 [00:37<00:00,  6.22s/it]

--------------- Epoch 58 ---------------

100%|| 6/6 [00:37<00:00,  6.22s/it]

--------------- Epoch 59 ---------------

100%|| 6/6 [00:37<00:00,  6.18s/it]

--------------- Epoch 60 ---------------

100%|| 6/6 [00:37<00:00,  6.19s/it]

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Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 61 ---------------

100%|| 6/6 [00:37<00:00,  6.20s/it]

--------------- Epoch 62 ---------------
```
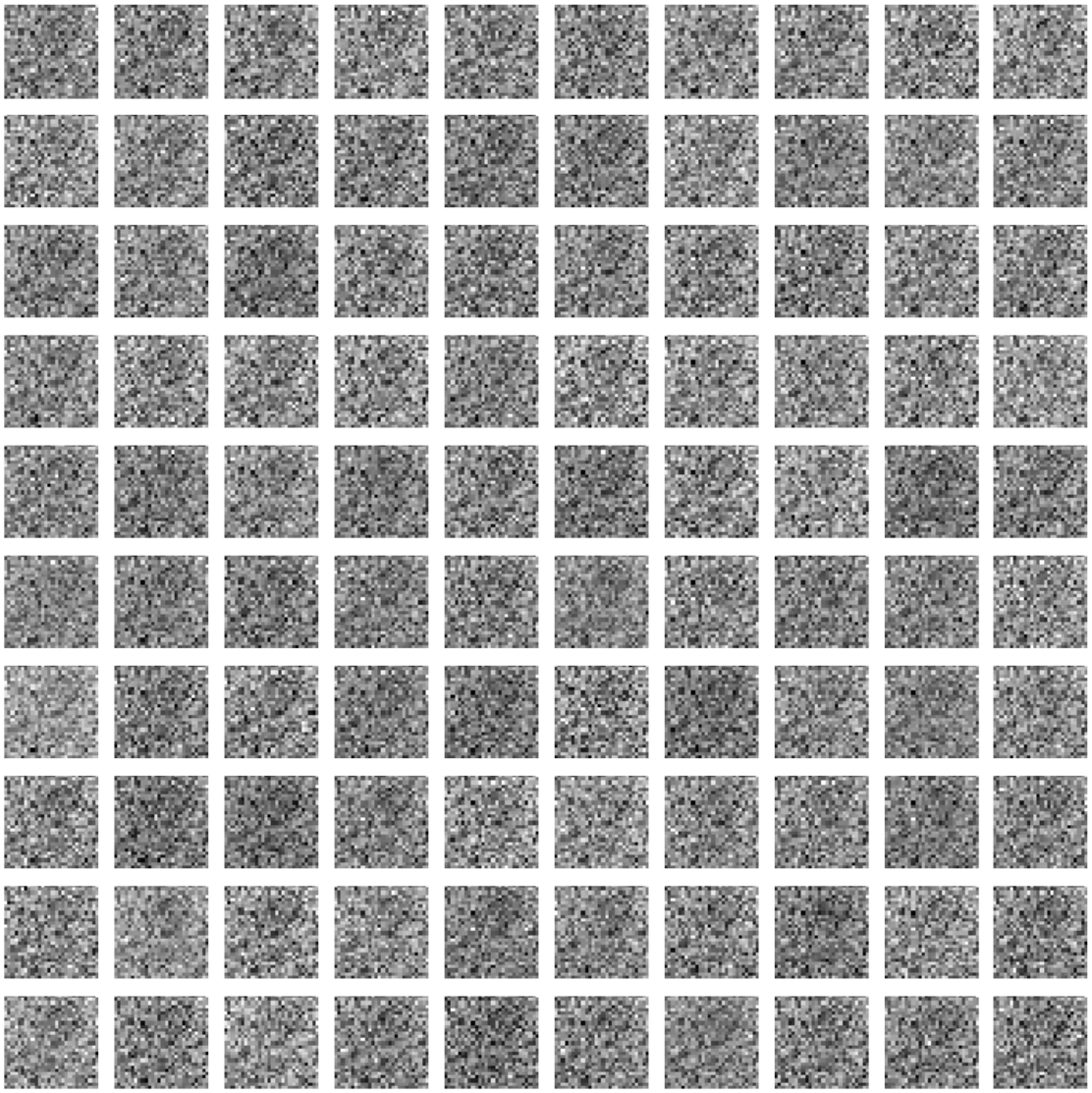
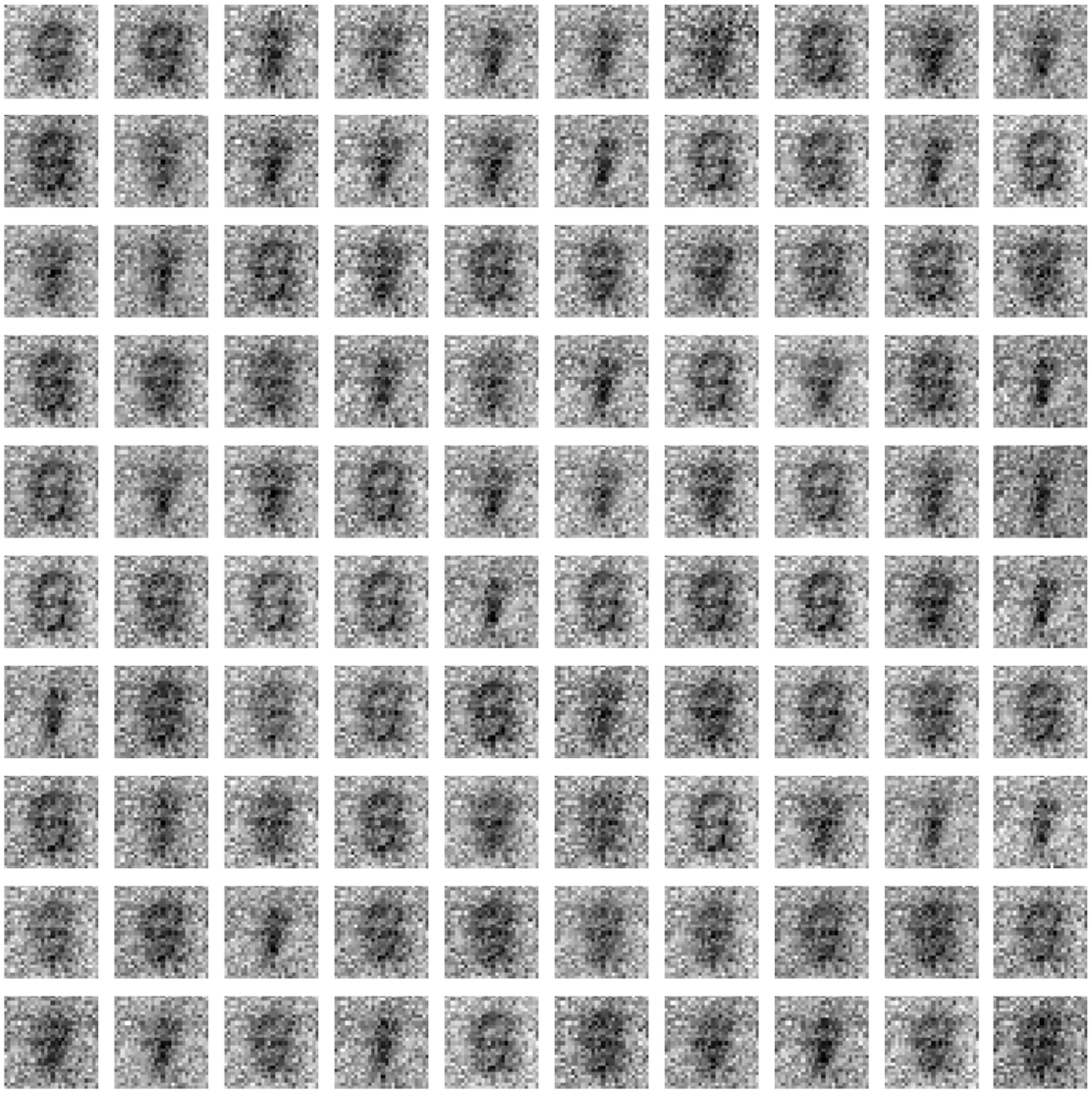
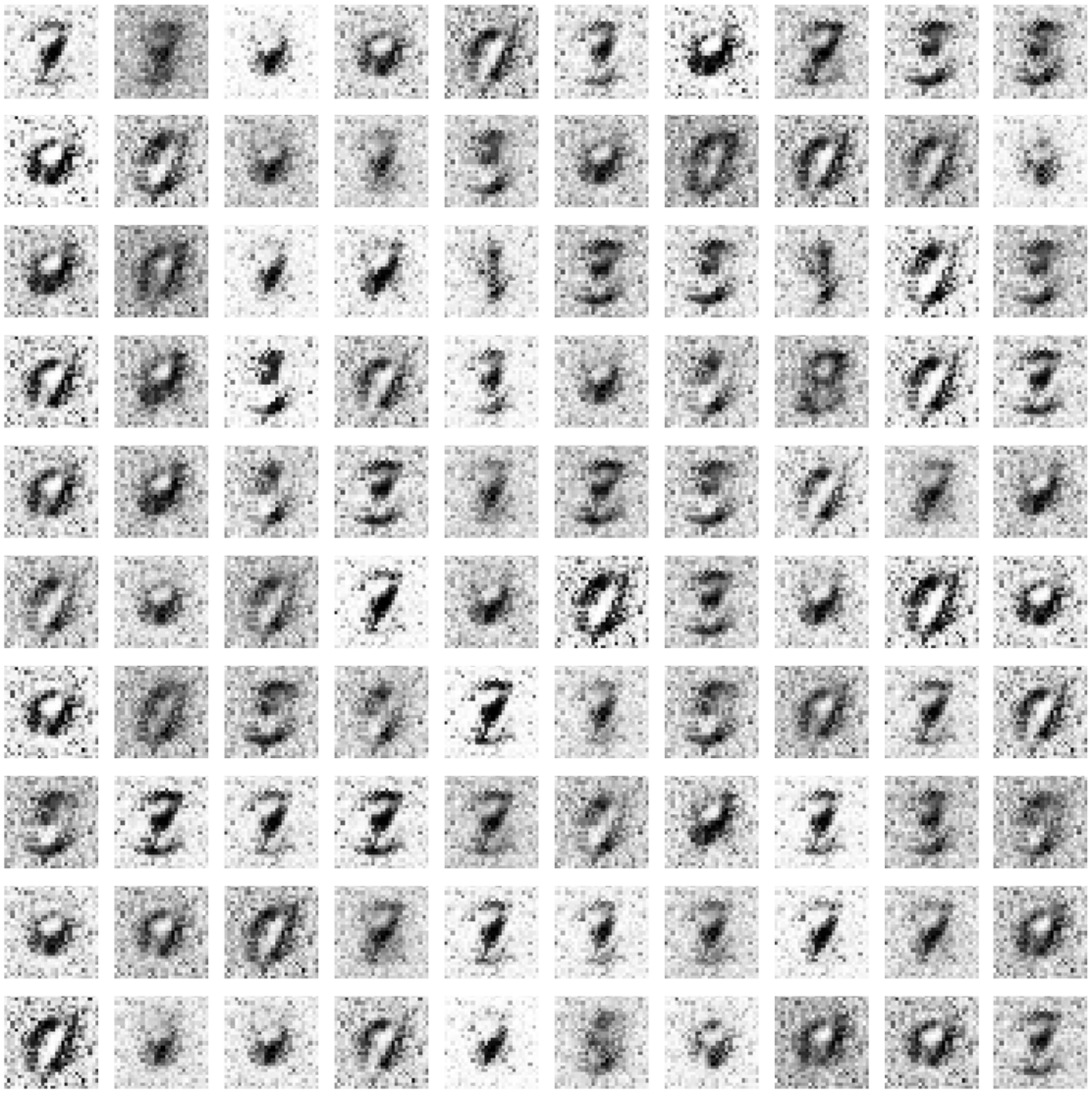

```
100%|| 6/6 [00:37<00:00,  6.28s/it]
--------------- Epoch 63 ---------------
100%|| 6/6 [00:37<00:00,  6.28s/it]
--------------- Epoch 64 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 65 ---------------
100%|| 6/6 [00:37<00:00,  6.24s/it]
--------------- Epoch 66 ---------------
100%|| 6/6 [00:37<00:00,  6.26s/it]
--------------- Epoch 67 ---------------
100%|| 6/6 [00:37<00:00,  6.28s/it]
--------------- Epoch 68 ---------------
100%|| 6/6 [00:37<00:00,  6.26s/it]
--------------- Epoch 69 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 70 ---------------
100%|| 6/6 [00:37<00:00,  6.25s/it]
--------------- Epoch 71 ---------------
100%|| 6/6 [00:37<00:00,  6.21s/it]
--------------- Epoch 72 ---------------
100%|| 6/6 [00:37<00:00,  6.26s/it]
--------------- Epoch 73 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 74 ---------------
100%|| 6/6 [00:37<00:00,  6.22s/it]
--------------- Epoch 75 ---------------
100%|| 6/6 [00:37<00:00,  6.19s/it]
```

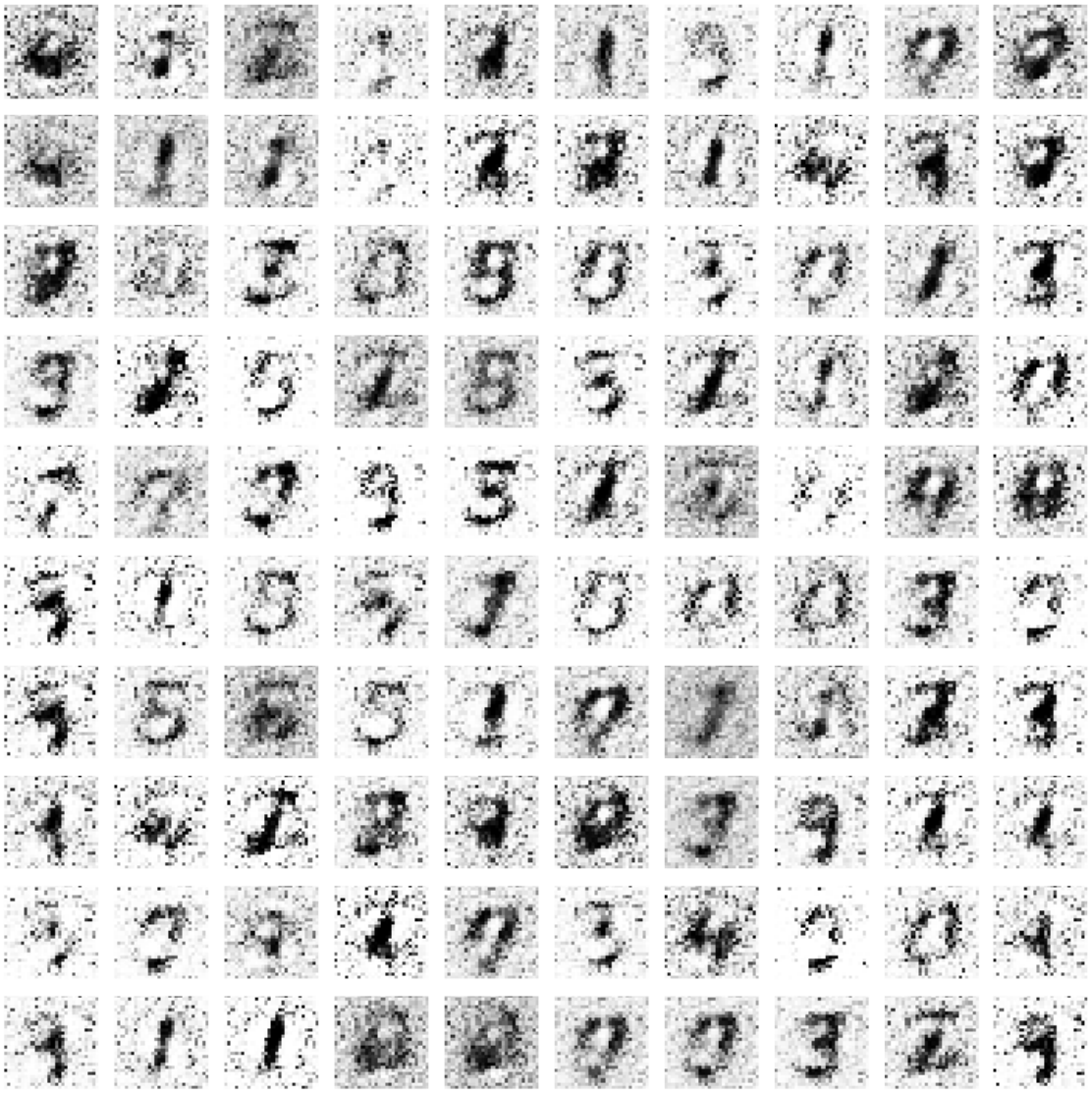
```
--------------- Epoch 76 ---------------

100%|| 6/6 [00:37<00:00,  6.26s/it]

--------------- Epoch 77 ---------------

100%|| 6/6 [00:37<00:00,  6.28s/it]

--------------- Epoch 78 ---------------

100%|| 6/6 [00:36<00:00,  6.16s/it]

--------------- Epoch 79 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 80 ---------------

100%|| 6/6 [00:37<00:00,  6.23s/it]

/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
--------------- Epoch 81 ---------------

100%|| 6/6 [00:37<00:00,  6.32s/it]

--------------- Epoch 82 ---------------

100%|| 6/6 [00:37<00:00,  6.32s/it]

--------------- Epoch 83 ---------------

100%|| 6/6 [00:37<00:00,  6.26s/it]

--------------- Epoch 84 ---------------

100%|| 6/6 [00:37<00:00,  6.30s/it]

--------------- Epoch 85 ---------------

100%|| 6/6 [00:37<00:00,  6.32s/it]

--------------- Epoch 86 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 87 ---------------

100%|| 6/6 [00:37<00:00,  6.22s/it]

--------------- Epoch 88 ---------------
```

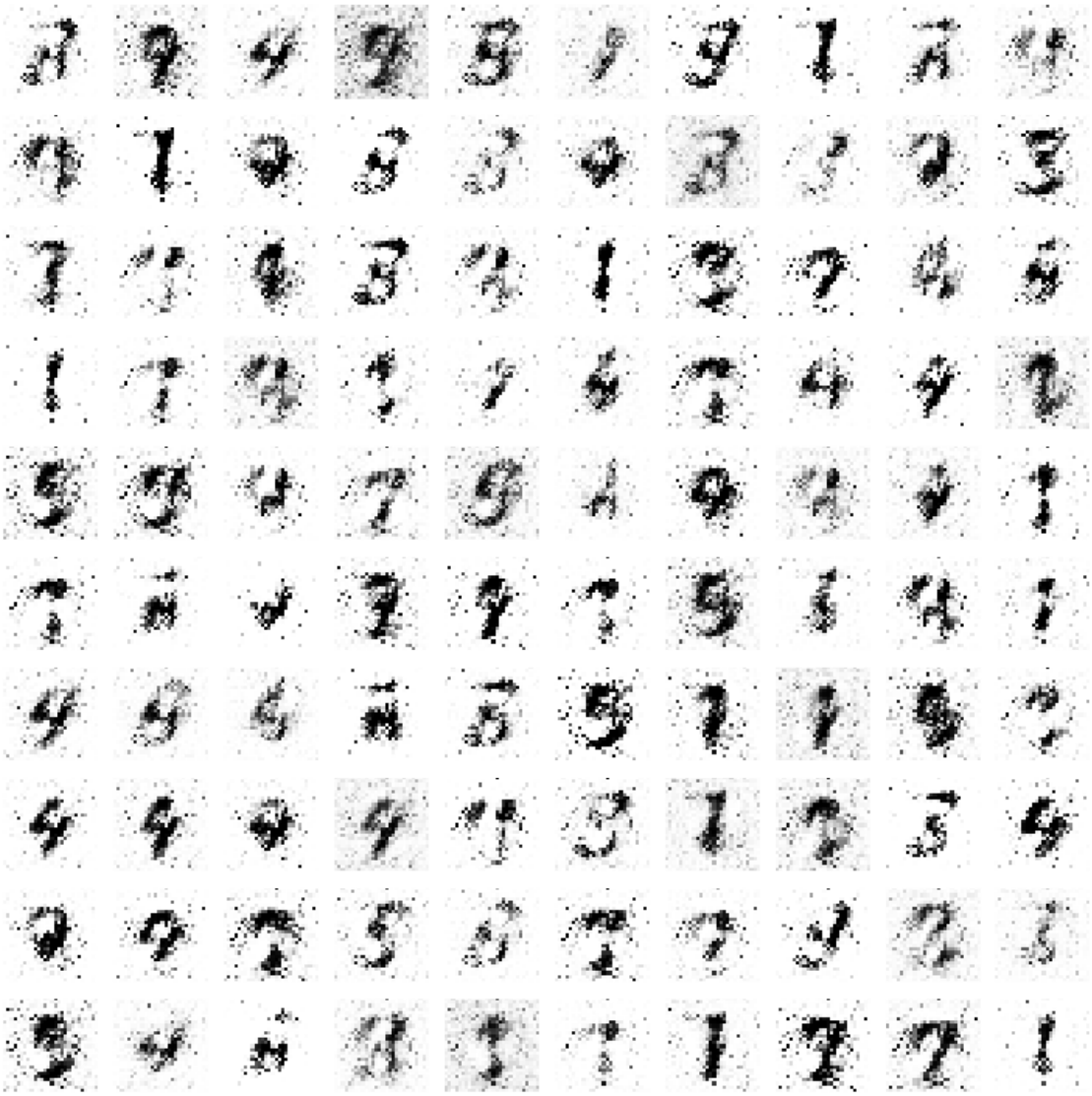
```
100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 89 ---------------

100%|| 6/6 [00:37<00:00,  6.20s/it]

--------------- Epoch 90 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 91 ---------------

100%|| 6/6 [00:37<00:00,  6.24s/it]

--------------- Epoch 92 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 93 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 94 ---------------

100%|| 6/6 [00:37<00:00,  6.30s/it]

--------------- Epoch 95 ---------------

100%|| 6/6 [00:37<00:00,  6.25s/it]

--------------- Epoch 96 ---------------

100%|| 6/6 [00:37<00:00,  6.25s/it]

--------------- Epoch 97 ---------------

100%|| 6/6 [00:37<00:00,  6.27s/it]

--------------- Epoch 98 ---------------

100%|| 6/6 [00:37<00:00,  6.32s/it]

--------------- Epoch 99 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

--------------- Epoch 100 ---------------

100%|| 6/6 [00:37<00:00,  6.29s/it]

/content/drive/MyDrive/American_University/2021_Fall/DATA-642-001_Advanced
Machine Learning/GitHub/Labs/10/submit
```

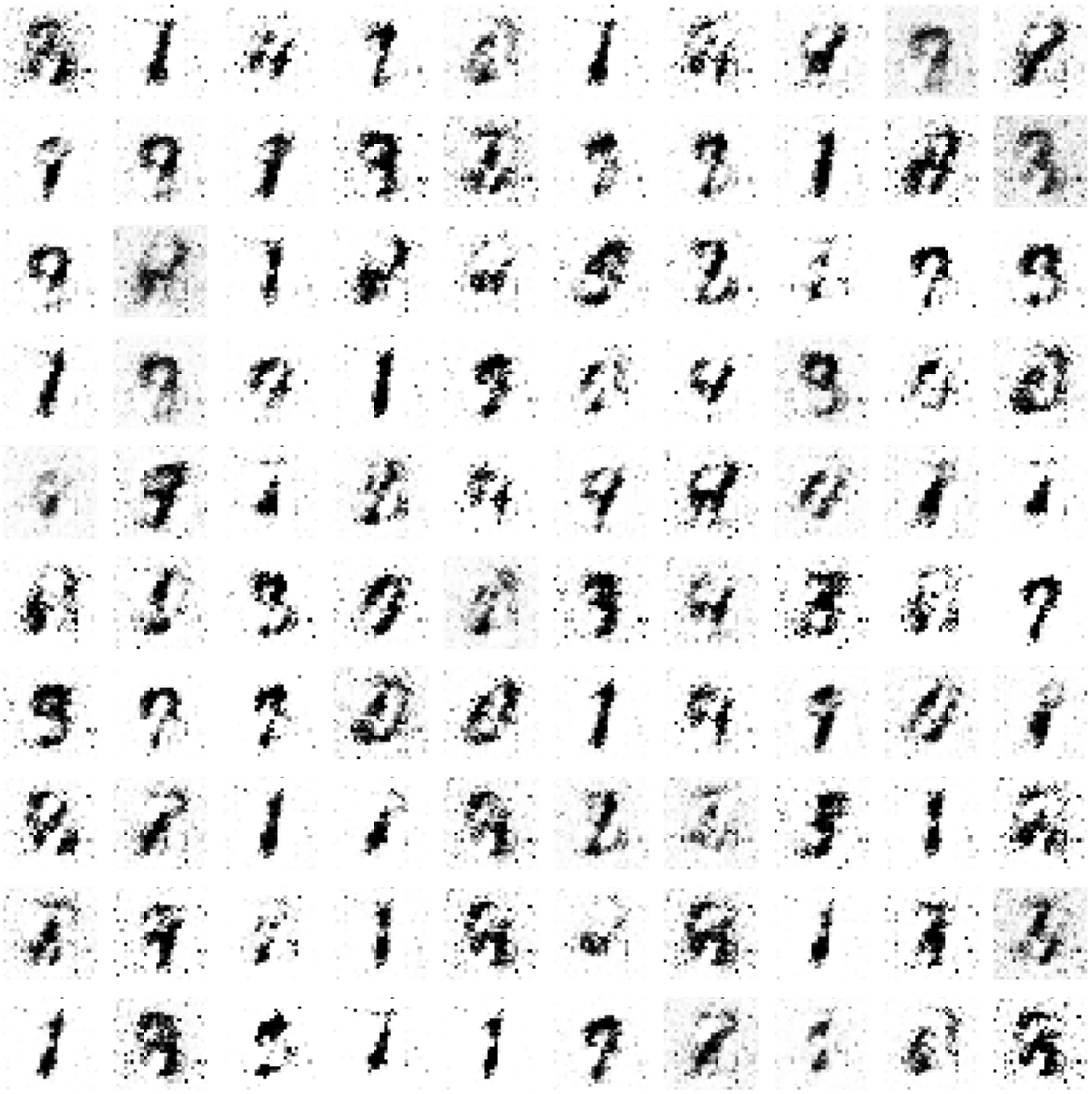












We must use activation functions such as ReLu, sigmoid and tanh in order to add a **non-linear** property to the neural network. In this way, the network can model more complex relationships and patterns in the data.

4 References

- https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/#:~:text=Adam%20is%20a%20replacement%20optimization,sparse%20gradients%20on%20noisy
- https://towardsdatascience.com/activation-functions-in-deep-neural-networks-aae2a598f211
- https://machinelearningmastery.com/difference-between-a-batch-and-an-epoch/

5 Output

[18]:
```
# should access the Google Drive files before running the chunk
%%capture
!sudo apt-get install texlive-xetex texlive-fonts-recommended␣
↪texlive-plain-generic
!jupyter nbconvert --to pdf "/content/drive/MyDrive/American_University/
↪2021_Fall/DATA-642-001_Advanced Machine Learning/GitHub/Labs/10/submit/
↪Lab10_Yunting.ipynb"
```