

<b>Exp No: 7</b>	<b>Generative Models with GANs: Creating and Training a Generative Adversarial Network</b>
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**Aim:**

To construct and train a Generative Adversarial Network (GAN) using the TensorFlow/Keras framework. The objective is to train the GAN on the MNIST dataset to generate new, synthetic images of handwritten digits that are indistinguishable from the original training data.

**Algorithm:**

**Generative Adversarial Networks (GANs)**

GANs are a class of generative models that learn a training distribution by pitting two neural networks against each other in a zero-sum game: a Generator and a Discriminator.

**1. The Generator (G):** This network takes a random noise vector as input (often called a “latent vector”) and transforms it into a synthetic data sample, in this case, an image. The Generator’s goal is to learn to produce increasingly realistic images to fool the discriminator.

**2. The Discriminator (D):** This is a binary classifier network. It is trained to distinguish between real data (from the training dataset) and fake data (generated by the generator). Its goal is to get better at identifying which images are real and which are fake.

**3. The Adversarial Process:**

Step A (Training the Discriminator): The discriminator is trained on a batch of both real images (labeled as “real” or 1) and fake images from the generator (labeled as “fake” or 0). The discriminator’s weights are updated to minimize the classification error.

Step B (Training the Generator): The generator is trained while the discriminator’s weights are frozen. The generator creates fake images and feeds them to the discriminator. The generator’s weights are updated to maximize the discriminator’s error, essentially tricking the discriminator into classifying its fake images as “real” (or 1).

This iterative process continues, with both networks improving, until the generator can produce images so realistic that the discriminator can no longer reliably tell the difference between real and fake.



**CODE:**

```
# Import necessary libraries
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras.datasets import mnist
import os

# Suppress TensorFlow warnings for cleaner output
tf.keras.utils.disable_interactive_logging()

# --- Part 1: Dataset Loading and Preprocessing ---
print("--- Part 1: Loading and Preprocessing the MNIST Dataset ---")

(x_train, _), (_, _) = mnist.load_data()

x_train = x_train.reshape(x_train.shape[0], 28, 28, 1).astype('float32')
x_train = (x_train - 127.5) / 127.5 # Normalize to [-1, 1]

print(f"Normalized training data shape: {x_train.shape}")
print("Example of a normalized pixel value:", x_train[0, 0, 0, 0])

# --- Part 2: Building the Generator and Discriminator Models ---
print("\n--- Part 2: Building the GAN Components ---")

latent_dim = 100

# Generator
def build_generator():
    model = keras.Sequential(name="generator")
    model.add(layers.Dense(7 * 7 * 256, use_bias=False, input_shape=(latent_dim,)))
    model.add(layers.BatchNormalization())
    model.add(layers.LeakyReLU())
    model.add(layers.Reshape((7, 7, 256)))
    model.add(layers.Conv2DTranspose(128, (5, 5), strides=(1, 1), padding='same',
    use_bias=False))
    model.add(layers.BatchNormalization())
    model.add(layers.LeakyReLU())
```



```

        model.add(layers.Conv2DTranspose(64, (5, 5), strides=(2, 2), padding='same',
use_bias=False))
        model.add(layers.BatchNormalization())
        model.add(layers.LeakyReLU())
        model.add(layers.Conv2DTranspose(1, (5, 5), strides=(2, 2), padding='same',
use_bias=False, activation='tanh'))

    return model

generator = build_generator()
print("\n--- Generator Model Summary ---")
generator.summary()

# Discriminator
def build_discriminator():
    model = keras.Sequential(name="discriminator")
    model.add(layers.Conv2D(64, (5, 5), strides=(2, 2), padding='same', input_shape=[28, 28,
1]))
    model.add(layers.LeakyReLU())
    model.add(layers.Dropout(0.3))
    model.add(layers.Conv2D(128, (5, 5), strides=(2, 2), padding='same'))
    model.add(layers.LeakyReLU())
    model.add(layers.Dropout(0.3))
    model.add(layers.Flatten())
    model.add(layers.Dense(1, activation='sigmoid'))
    return model

discriminator = build_discriminator()
print("\n--- Discriminator Model Summary ---")
discriminator.summary()

# --- Part 3: Training Setup ---
cross_entropy = keras.losses.BinaryCrossentropy(from_logits=False)

def discriminator_loss(real_output, fake_output):
    real_loss = cross_entropy(tf.ones_like(real_output), real_output)
    fake_loss = cross_entropy(tf.zeros_like(fake_output), fake_output)
    return real_loss + fake_loss

def generator_loss(fake_output):
    return cross_entropy(tf.ones_like(fake_output), fake_output)

```



```

generator_optimizer = tf.keras.optimizers.Adam(learning_rate=1e-4)
discriminator_optimizer = tf.keras.optimizers.Adam(learning_rate=1e-4)

@tf.function
def train_step(images, latent_dim=latent_dim):
    noise = tf.random.normal([batch_size, latent_dim])
    with tf.GradientTape() as gen_tape, tf.GradientTape() as disc_tape:
        generated_images = generator(noise, training=True)
        real_output = discriminator(images, training=True)
        fake_output = discriminator(generated_images, training=True)
        gen_loss = generator_loss(fake_output)
        disc_loss = discriminator_loss(real_output, fake_output)
        gradients_of_generator = gen_tape.gradient(gen_loss, generator.trainable_variables)
        gradients_of_discriminator = disc_tape.gradient(disc_loss,
discriminator.trainable_variables)
        generator_optimizer.apply_gradients(zip(gradients_of_generator,
generator.trainable_variables))
        discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator,
discriminator.trainable_variables))
    return gen_loss, disc_loss

def generate_and_save_images(model, epoch, test_input):
    predictions = model(test_input, training=False)
    predictions_rescaled = (predictions * 0.5) + 0.5 # Scale back to [0, 1]
    fig = plt.figure(figsize=(4, 4))
    for i in range(predictions.shape[0]):
        plt.subplot(4, 4, i + 1)
        plt.imshow(predictions_rescaled[i, :, :, 0], cmap='gray')
        plt.axis('off')
    plt.suptitle(f'Epoch {epoch}', fontsize=16)
    if not os.path.exists('images'):
        os.makedirs('images')
    plt.savefig(f'images/image_at_epoch_{epoch:04d}.png')
    plt.show()

# Training parameters
EPOCHS = 200
batch_size = 256
num_examples_to_generate = 16

```



```

seed = tf.random.normal([num_examples_to_generate, latent_dim])

train_dataset =
tf.data.Dataset.from_tensor_slices(x_train).shuffle(x_train.shape[0]).batch(batch_size)

# Training loop
def train(dataset, epochs):
    print("\n--- Beginning GAN Training ---")
    for epoch in range(epochs):
        gen_loss_list = []
        disc_loss_list = []
        for image_batch in dataset:
            gen_loss, disc_loss = train_step(image_batch)
            gen_loss_list.append(gen_loss.numpy())
            disc_loss_list.append(disc_loss.numpy())
        avg_gen_loss = np.mean(gen_loss_list)
        avg_disc_loss = np.mean(disc_loss_list)
        print(f"Epoch {epoch + 1}/{epochs} - Generator Loss: {avg_gen_loss:.4f},
Discriminator Loss: {avg_disc_loss:.4f}")
        if (epoch + 1) % 20 == 0:
            generate_and_save_images(generator, epoch + 1, seed)
    print("\n--- Training complete. Generating final images. ---")
    generate_and_save_images(generator, epochs, seed)

# Run training
train(train_dataset, EPOCHS)

```

## OUTPUT:

--- Part 1: Loading and Preprocessing the MNIST Dataset ---

Normalized training data shape: (60000, 28, 28, 1)

Example normalized pixel value: -1.0

--- Beginning GAN Training ---

Epoch 1/20 - Generator Loss: 0.7877, Discriminator Loss: 1.0228

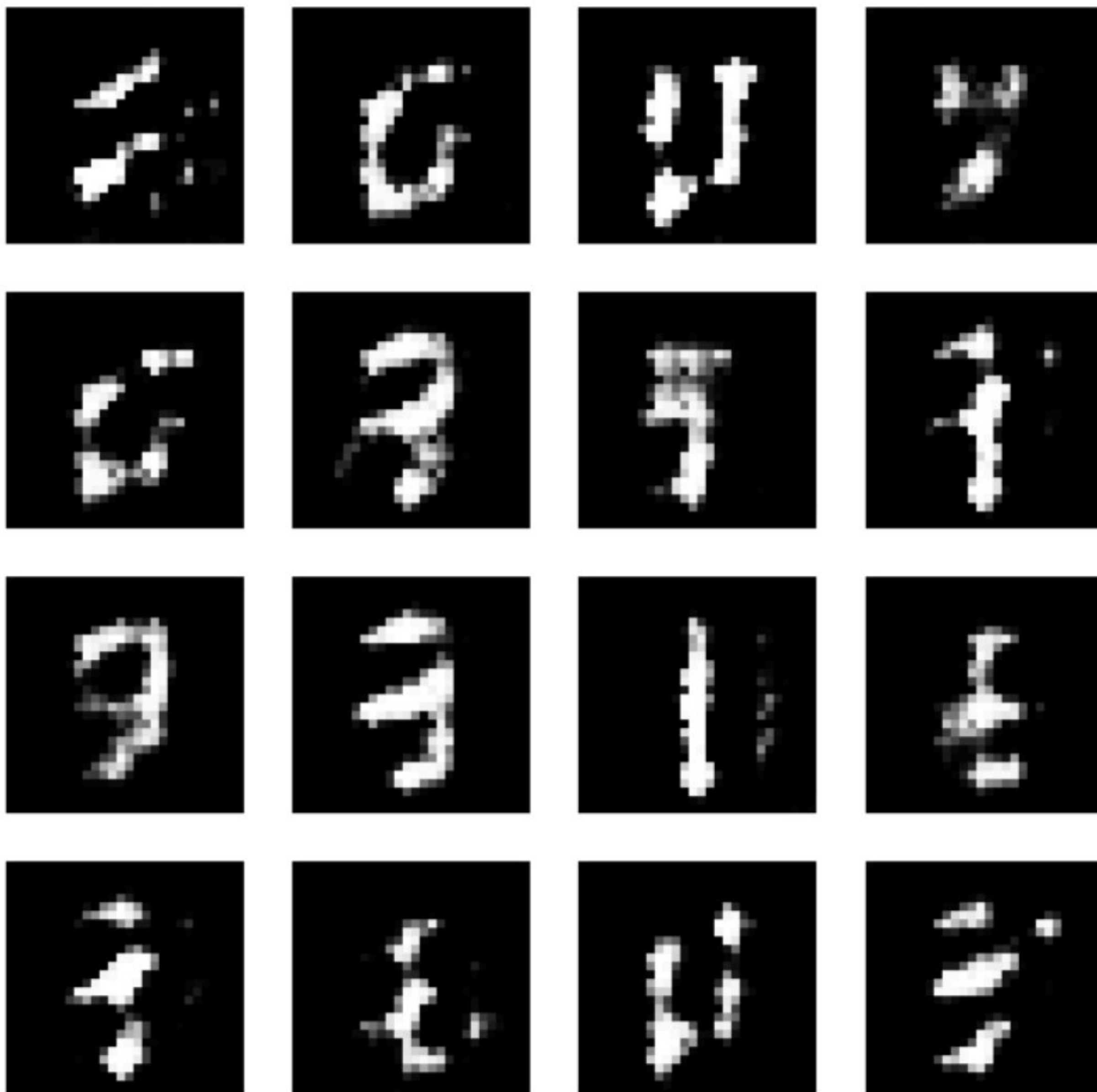
Epoch 2/20 - Generator Loss: 0.8148, Discriminator Loss: 1.2225

Epoch 3/20 - Generator Loss: 0.8448, Discriminator Loss: 1.3034

Epoch 4/20 - Generator Loss: 0.8534, Discriminator Loss: 1.2366

Epoch 5/20 - Generator Loss: 0.8372, Discriminator Loss: 1.2497

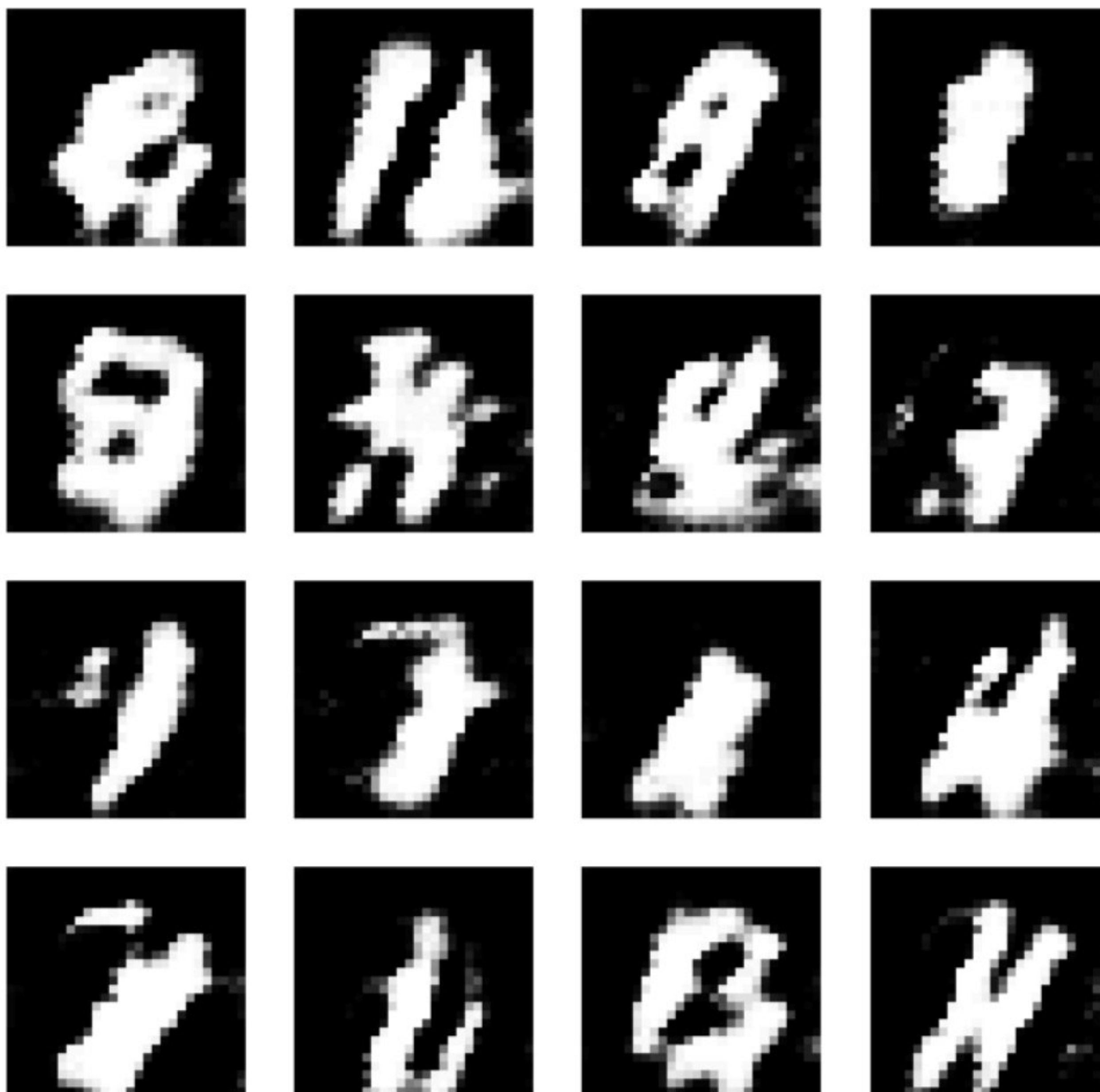
Epoch 5





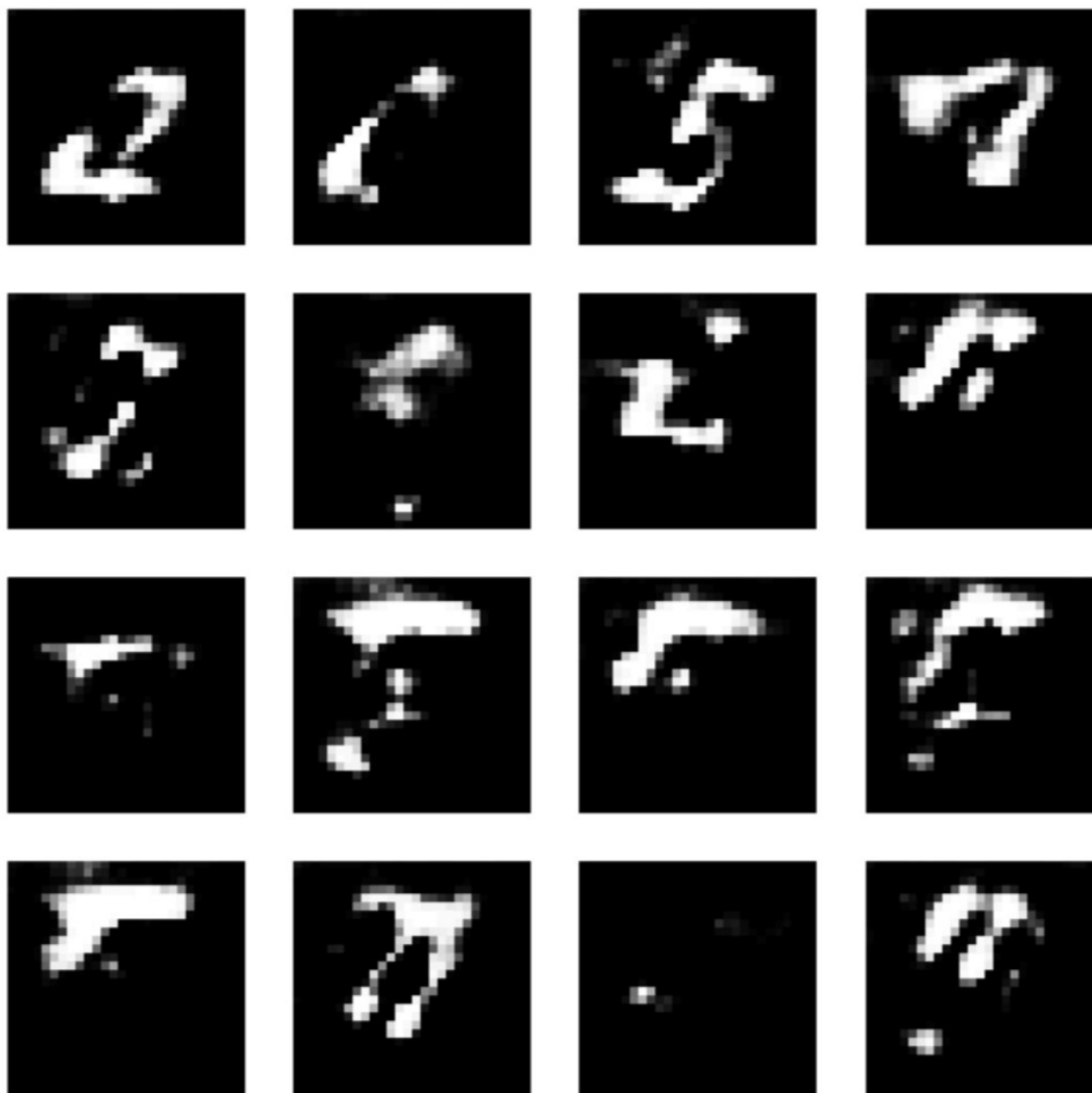
Epoch 6/20 - Generator Loss: 0.8516, Discriminator Loss: 1.2705  
Epoch 7/20 - Generator Loss: 0.8888, Discriminator Loss: 1.3028  
Epoch 8/20 - Generator Loss: 0.8739, Discriminator Loss: 1.2512  
Epoch 9/20 - Generator Loss: 0.8691, Discriminator Loss: 1.3130  
Epoch 10/20 - Generator Loss: 0.8862, Discriminator Loss: 1.2320

Epoch 10



Epoch 11/20 - Generator Loss: 0.9361, Discriminator Loss: 1.2244  
Epoch 12/20 - Generator Loss: 0.9946, Discriminator Loss: 1.1719  
Epoch 13/20 - Generator Loss: 0.9948, Discriminator Loss: 1.1944  
Epoch 14/20 - Generator Loss: 0.9786, Discriminator Loss: 1.1809  
Epoch 15/20 - Generator Loss: 1.0420, Discriminator Loss: 1.1079

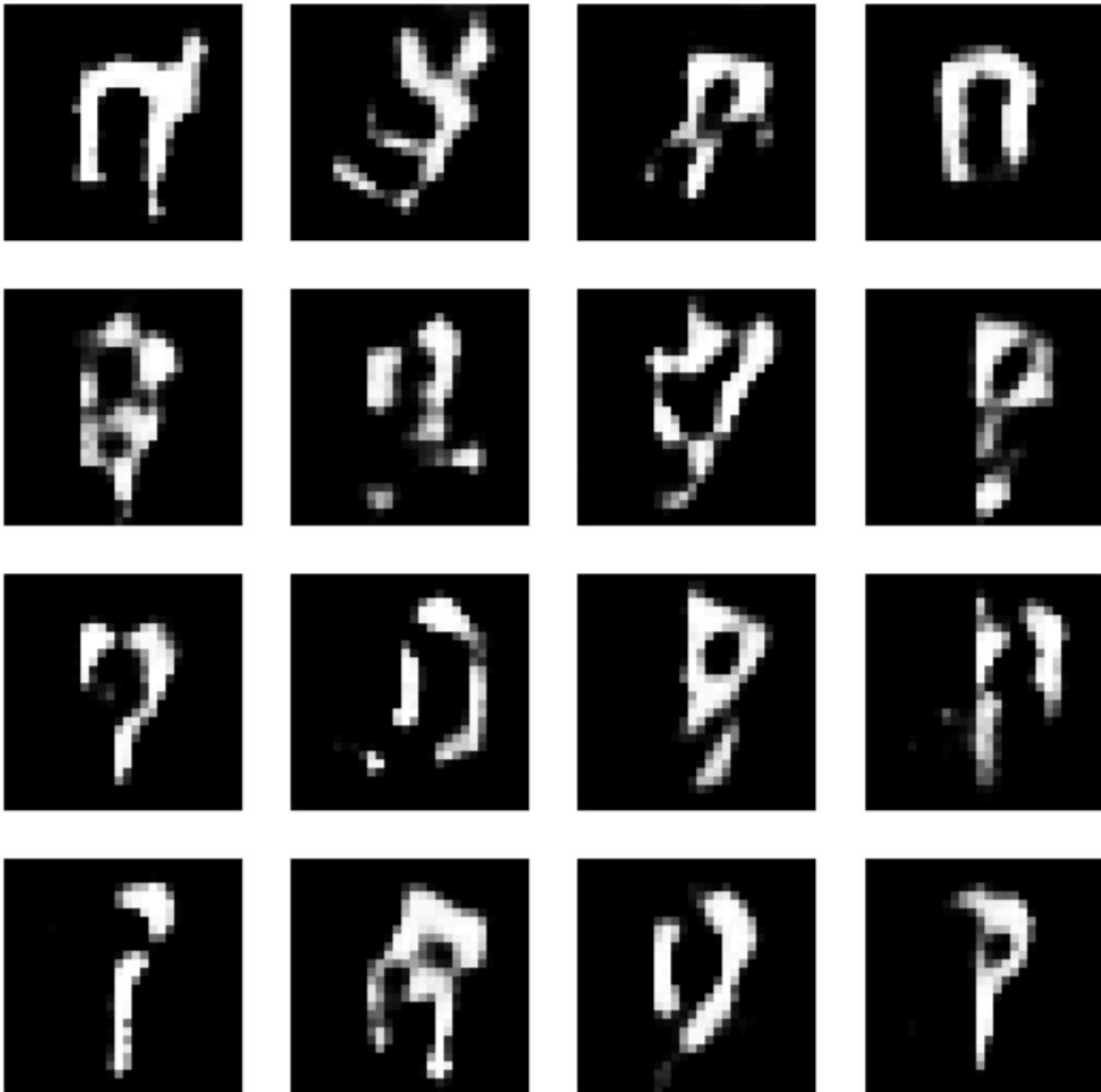
## Epoch 15





Epoch 16/20 - Generator Loss: 1.2020, Discriminator Loss: 1.0483  
Epoch 17/20 - Generator Loss: 1.2648, Discriminator Loss: 1.0605  
Epoch 18/20 - Generator Loss: 1.1657, Discriminator Loss: 1.0404  
Epoch 19/20 - Generator Loss: 1.1644, Discriminator Loss: 1.0897  
Epoch 20/20 - Generator Loss: 1.1770, Discriminator Loss: 1.0938

## Epoch 20





--- Training complete. Generating final images. ---

Epoch 20

