import numpy as np  
import matplotlib.pyplot as plt  
from tensorflow import keras  
from tensorflow.keras import layers  
  
# Generate a small dataset of squares  
num\_samples = 100  
image\_size = 16  
  
# Generate random squares  
X\_train = np.zeros((num\_samples, image\_size, image\_size, 1))  
for i in range(num\_samples):  
 x = np.random.randint(0, image\_size - 4)  
 y = np.random.randint(0, image\_size - 4)  
 X\_train[i, x:x+4, y:y+4, 0] = 1.0  
  
# Define the generator model  
latent\_dim = 10  
  
generator = keras.Sequential([  
 keras.Input(shape=(latent\_dim,)),  
 layers.Dense(8 \* 8 \* 16),  
 layers.Reshape((8, 8, 16)),  
 layers.Conv2DTranspose(32, 4, strides=2, padding="same"),  
 layers.LeakyReLU(alpha=0.2),  
 layers.Conv2D(1, 3, activation="sigmoid", padding="same"),  
])  
  
# Define the discriminator model  
discriminator = keras.Sequential([  
 keras.Input(shape=(image\_size, image\_size, 1)),  
 layers.Conv2D(32, 3, strides=2, padding='same'),  
 layers.LeakyReLU(alpha=0.2),  
 layers.Flatten(),  
 layers.Dense(1, activation="sigmoid"),  
])  
  
# Compile the discriminator  
discriminator.compile(optimizer=keras.optimizers.Adam(learning\_rate=0.0002, beta\_1=0.5), loss="binary\_crossentropy")  
  
# Combine the generator and discriminator into a GAN  
discriminator.trainable = False  
gan\_input = keras.Input(shape=(latent\_dim,))  
gan\_output = discriminator(generator(gan\_input))  
gan = keras.models.Model(gan\_input, gan\_output)  
gan.compile(optimizer=keras.optimizers.Adam(learning\_rate=0.0002, beta\_1=0.5), loss="binary\_crossentropy")  
  
# Training loop  
epochs = 20  
batch\_size = 10  
  
for epoch in range(epochs):  
 print(f"Epoch {epoch+1}/{epochs}")  
 for \_ in range(num\_samples // batch\_size):  
 # Train the discriminator  
 noise = np.random.normal(0, 1, (batch\_size, latent\_dim))  
 generated\_images = generator.predict(noise)  
 real\_images = X\_train[np.random.randint(0, X\_train.shape[0], batch\_size)]  
 combined\_images = np.concatenate([generated\_images, real\_images])  
 labels = np.concatenate([np.zeros((batch\_size, 1)), np.ones((batch\_size, 1))])  
 labels += 0.05 \* np.random.random(labels.shape)  
 discriminator\_loss = discriminator.train\_on\_batch(combined\_images, labels)  
  
 # Train the generator  
 noise = np.random.normal(0, 1, (batch\_size, latent\_dim))  
 misleading\_targets = np.ones((batch\_size, 1))  
 generator\_loss = gan.train\_on\_batch(noise, misleading\_targets)  
  
 # Visualize the progress  
 print(f"Discriminator loss: {discriminator\_loss}")  
 print(f"Generator loss: {generator\_loss}")  
  
# Generate and save some sample images  
num\_samples = 10  
noise = np.random.normal(0, 1, (num\_samples, latent\_dim))  
generated\_images = generator.predict(noise)  
  
for i in range(num\_samples):  
 plt.imshow(generated\_images[i].reshape(image\_size, image\_size), cmap="gray")  
 plt.axis("off")  
 plt.savefig(f"generated\_image\_{i}.png")  
 plt.show()

Epoch 1/20  
1/1 [==============================] - 0s 334ms/step  
1/1 [==============================] - 0s 31ms/step  
1/1 [==============================] - 0s 29ms/step  
1/1 [==============================] - 0s 31ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 30ms/step  
1/1 [==============================] - 0s 30ms/step  
1/1 [==============================] - 0s 31ms/step  
1/1 [==============================] - 0s 28ms/step  
Discriminator loss: 0.6353934407234192  
Generator loss: 0.8521708250045776  
Epoch 2/20  
1/1 [==============================] - 0s 42ms/step  
1/1 [==============================] - 0s 35ms/step  
1/1 [==============================] - 0s 36ms/step  
1/1 [==============================] - 0s 37ms/step  
1/1 [==============================] - 0s 36ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 36ms/step  
1/1 [==============================] - 0s 71ms/step  
1/1 [==============================] - 0s 45ms/step  
Discriminator loss: 0.6078013181686401  
Generator loss: 0.9616401791572571  
Epoch 3/20  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 35ms/step  
1/1 [==============================] - 0s 36ms/step  
1/1 [==============================] - 0s 39ms/step  
1/1 [==============================] - 0s 41ms/step  
1/1 [==============================] - 0s 46ms/step  
1/1 [==============================] - 0s 42ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 43ms/step  
Discriminator loss: 0.5773860216140747  
Generator loss: 1.0780079364776611  
Epoch 4/20  
1/1 [==============================] - 0s 57ms/step  
1/1 [==============================] - 0s 45ms/step  
1/1 [==============================] - 0s 83ms/step  
1/1 [==============================] - 0s 51ms/step  
1/1 [==============================] - 0s 40ms/step  
1/1 [==============================] - 0s 46ms/step  
1/1 [==============================] - 0s 40ms/step  
1/1 [==============================] - 0s 43ms/step  
1/1 [==============================] - 0s 35ms/step  
1/1 [==============================] - 0s 57ms/step  
Discriminator loss: 0.5503563284873962  
Generator loss: 1.2011287212371826  
Epoch 5/20  
1/1 [==============================] - 0s 88ms/step  
1/1 [==============================] - 0s 64ms/step  
1/1 [==============================] - 0s 58ms/step  
1/1 [==============================] - 0s 51ms/step  
1/1 [==============================] - 0s 123ms/step  
1/1 [==============================] - 0s 152ms/step  
1/1 [==============================] - 0s 138ms/step  
1/1 [==============================] - 0s 129ms/step  
1/1 [==============================] - 0s 56ms/step  
1/1 [==============================] - 0s 75ms/step  
Discriminator loss: 0.5313212275505066  
Generator loss: 1.3100839853286743  
Epoch 6/20  
1/1 [==============================] - 0s 62ms/step  
1/1 [==============================] - 0s 66ms/step  
1/1 [==============================] - 0s 160ms/step  
1/1 [==============================] - 0s 74ms/step  
1/1 [==============================] - 0s 39ms/step  
1/1 [==============================] - 0s 49ms/step  
1/1 [==============================] - 0s 52ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 44ms/step  
Discriminator loss: 0.49456366896629333  
Generator loss: 1.4074710607528687  
Epoch 7/20  
1/1 [==============================] - 0s 98ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 61ms/step  
1/1 [==============================] - 0s 111ms/step  
1/1 [==============================] - 0s 75ms/step  
1/1 [==============================] - 0s 51ms/step  
1/1 [==============================] - 0s 43ms/step  
1/1 [==============================] - 0s 44ms/step  
1/1 [==============================] - 0s 47ms/step  
1/1 [==============================] - 0s 73ms/step  
Discriminator loss: 0.4632924199104309  
Generator loss: 1.5044844150543213  
Epoch 8/20  
1/1 [==============================] - 0s 103ms/step  
1/1 [==============================] - 0s 57ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 36ms/step  
1/1 [==============================] - 0s 47ms/step  
1/1 [==============================] - 0s 45ms/step  
1/1 [==============================] - 0s 69ms/step  
1/1 [==============================] - 0s 102ms/step  
1/1 [==============================] - 0s 37ms/step  
1/1 [==============================] - 0s 63ms/step  
Discriminator loss: 0.4401407241821289  
Generator loss: 1.5378172397613525  
Epoch 9/20  
1/1 [==============================] - 0s 40ms/step  
1/1 [==============================] - 0s 45ms/step  
1/1 [==============================] - 0s 116ms/step  
1/1 [==============================] - 0s 83ms/step  
1/1 [==============================] - 0s 49ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 37ms/step  
1/1 [==============================] - 0s 31ms/step  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 36ms/step  
Discriminator loss: 0.393228679895401  
Generator loss: 1.5322002172470093  
Epoch 10/20  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 63ms/step  
1/1 [==============================] - 0s 46ms/step  
1/1 [==============================] - 0s 35ms/step  
1/1 [==============================] - 0s 41ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 23ms/step  
Discriminator loss: 0.3748014569282532  
Generator loss: 1.4743200540542603  
Epoch 11/20  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 26ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 27ms/step  
1/1 [==============================] - 0s 26ms/step  
1/1 [==============================] - 0s 27ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 23ms/step  
Discriminator loss: 0.370526522397995  
Generator loss: 1.4533072710037231  
Epoch 12/20  
1/1 [==============================] - 0s 27ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 29ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 26ms/step  
1/1 [==============================] - 0s 28ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
Discriminator loss: 0.3809732496738434  
Generator loss: 1.2825555801391602  
Epoch 13/20  
1/1 [==============================] - 0s 26ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 20ms/step  
1/1 [==============================] - 0s 26ms/step  
Discriminator loss: 0.4069640636444092  
Generator loss: 1.0653244256973267  
Epoch 14/20  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 30ms/step  
1/1 [==============================] - 0s 22ms/step  
Discriminator loss: 0.38339763879776  
Generator loss: 0.8786719441413879  
Epoch 15/20  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 21ms/step  
Discriminator loss: 0.4659644663333893  
Generator loss: 0.6655107140541077  
Epoch 16/20  
1/1 [==============================] - 0s 26ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 20ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
Discriminator loss: 0.5192636251449585  
Generator loss: 0.6124769449234009  
Epoch 17/20  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 20ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 20ms/step  
1/1 [==============================] - 0s 20ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
Discriminator loss: 0.5730112791061401  
Generator loss: 0.5581079721450806  
Epoch 18/20  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 27ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 21ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 23ms/step  
Discriminator loss: 0.6471648216247559  
Generator loss: 0.569907546043396  
Epoch 19/20  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 24ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 23ms/step  
1/1 [==============================] - 0s 25ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
1/1 [==============================] - 0s 22ms/step  
Discriminator loss: 0.6606127619743347  
Generator loss: 0.5545530915260315  
Epoch 20/20  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 33ms/step  
1/1 [==============================] - 0s 30ms/step  
1/1 [==============================] - 0s 30ms/step  
1/1 [==============================] - 0s 38ms/step  
1/1 [==============================] - 0s 50ms/step  
1/1 [==============================] - 0s 37ms/step  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 34ms/step  
1/1 [==============================] - 0s 34ms/step  
Discriminator loss: 0.6856497526168823  
Generator loss: 0.5580624341964722  
1/1 [==============================] - 0s 34ms/step



















