```
import tensorflow as tf
from tensorflow.keras.layers import (Dense,
                                     BatchNormalization,
                                     LeakyReLU,
                                     Reshape,
                                     Conv2DTranspose,
                                     Conv2D,
                                     Dropout,
                                     Flatten)
import matplotlib.pyplot as plt
```

Double-click (or enter) to edit

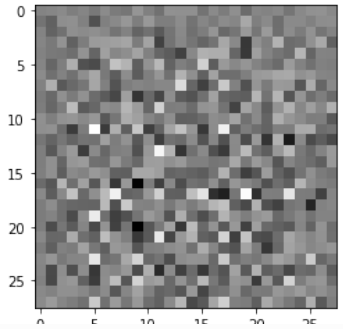
```
# underscore to omit the label arrays
(train_images, train_labels), (_, _) = tf.keras.datasets.mnist.load_data()


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

BUFFER_SIZE = 60000
BATCH_SIZE = 256

# Batch and shuffle the data
train_dataset = tf.data.Dataset.from_tensor_slices(train_images).shuffle(BUFFER_SIZE).batch
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 [==============================] - 0s 0us/step
```

```
def make_generator_model():
    model = tf.keras.Sequential()
    model.add(Dense(7*7*256, use_bias=False, input_shape=(100,)))
    model.add(BatchNormalization())
    model.add(LeakyReLU())

    model.add(Reshape((7, 7, 256)))
    assert model.output_shape == (None, 7, 7, 256) # Note: None is the batch size

    model.add(Conv2DTranspose(128, (5, 5), strides=(1, 1), padding='same', use_bias=False))
    assert model.output_shape == (None, 7, 7, 128)
    model.add(BatchNormalization())
    model.add(LeakyReLU())

    model.add(Conv2DTranspose(64, (5, 5), strides=(2, 2), padding='same', use_bias=False))
    assert model.output_shape == (None, 14, 14, 64)
    model.add(BatchNormalization())
    model.add(LeakyReLU())

    model.add(Conv2DTranspose(1, (5, 5), strides=(2, 2), padding='same', use_bias=False, ac
    assert model.output_shape == (None, 28, 28, 1)

    return model
```

```
generator = make_generator_model()

# Create a random noise and generate a sample
noise = tf.random.normal([1, 100])
generated_image = generator(noise, training=False)
# Visualize the generated sample
plt.imshow(generated_image[0, :, :, 0], cmap='gray')
```

```
<matplotlib.image.AxesImage at 0x7fa6343425e0>
```



```
def make_discriminator_model():
    model = tf.keras.Sequential()

    model.add(Conv2D(64, (5, 5), strides=(2, 2), padding='same', input_shape=[28, 28, 1]))
    model.add(LeakyReLU())
    model.add(Dropout(0.3))

    model.add(Conv2D(128, (5, 5), strides=(2, 2), padding='same'))
    model.add(LeakyReLU())
    model.add(Dropout(0.3))

    model.add(Flatten())
    model.add(Dense(1))

    return model

discriminator = make_discriminator_model()

decision = discriminator(generated_image)
print (decision)
```

```
tf.Tensor([[-0.00014858]], shape=(1, 1), dtype=float32)
```

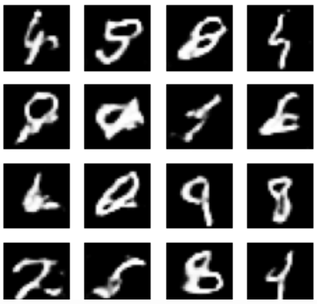
```
# This method returns a helper function to compute cross entropy loss
cross_entropy = tf.keras.losses.BinaryCrossentropy(from_logits=True)

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)
    total_loss = real_loss + fake_loss
    return total_loss

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

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

```
import os

checkpoint_dir = './training_checkpoints'
checkpoint_prefix = os.path.join(checkpoint_dir, "ckpt")
checkpoint = tf.train.Checkpoint(generator_optimizer=generator_optimizer, discriminator_opt
```

```
EPOCHS = 120
# We will reuse this seed overtime (so it's easier)
# to visualize progress in the animated GIF)
num_examples_to_generate = 16
noise_dim = 100
seed = tf.random.normal([num_examples_to_generate, noise_dim])
```

Start coding or generate with AI.

```
# tf.function annotation causes the function
# to be "compiled" as part of the training
@tf.function
def train_step(images):

    # 1 - Create a random noise to feed it into the model
    # for the image generation
    noise = tf.random.normal([BATCH_SIZE, noise_dim])

    # 2 - Generate images and calculate loss values
    # GradientTape method records operations for automatic differentiation.
    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)

    # 3 - Calculate gradients using loss values and model variables
    # "gradient" method computes the gradient using
    # operations recorded in context of this tape (gen_tape and disc_tape).

    # It accepts a target (e.g., gen_loss) variable and
    # a source variable (e.g.,generator.trainable_variables)
    # target --> a list or nested structure of Tensors or Variables to be differentiated.
    # source --> a list or nested structure of Tensors or Variables.
    # target will be differentiated against elements in sources.

    # "gradient" method returns a list or nested structure of Tensors
    # (or IndexedSlices, or None), one for each element in sources.
    # Returned structure is the same as the structure of sources.
    gradients_of_generator = gen_tape.gradient(gen_loss,
                                               generator.trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss,
                                                decriminator.trainable_variables)

    # 4 - Process  Gradients and Run the Optimizer
    # "apply_gradients" method processes aggregated gradients.
    # ex: optimizer.apply_gradients(zip(grads, vars))
    """
    Example use of apply_gradients:
    grads = tape.gradient(loss, vars)
    grads = tf.distribute.get_replica_context().all_reduce('sum', grads)
    # Processing aggregated gradients.
    optimizer.apply_gradients(zip(grads, vars), experimental_aggregate_gradients=False)
    """
    generator_optimizer.apply_gradients(zip(gradients_of_generator, generator.trainable_var
    discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator, discriminator.t

import time
from IPython import display # A command shell for interactive computing in Python.

def train(dataset, epochs):
  # A. For each epoch, do the following:
  for epoch in range(epochs):
    start = time.time()
    # 1 - For each batch of the epoch,
    for image_batch in dataset:
      # 1.a - run the custom "train_step" function
      # we just declared above
      train_step(image_batch)

    # 2 - Produce images for the GIF as we go
    display.clear_output(wait=True)
    generate_and_save_images(generator,
                             epoch + 1,
                             seed)

    # 3 - Save the model every 5 epochs as
    # a checkpoint, which we will use later
    if (epoch + 1) % 5 == 0:
      checkpoint.save(file_prefix = checkpoint_prefix)

    # 4 - Print out the completed epoch no. and the time spent
    print ('Time for epoch {} is {} sec'.format(epoch + 1, time.time()-start))

  # B. Generate a final image after the training is completed
  display.clear_output(wait=True)
  generate_and_save_images(generator,
                           epochs,
                           seed)


def generate_and_save_images(model, epoch, test_input):
  # Notice `training` is set to False.
  # This is so all layers run in inference mode (batchnorm).
  # 1 - Generate images
  predictions = model(test_input, training=False)
  # 2 - Plot the generated images
  fig = plt.figure(figsize=(4,4))
  for i in range(predictions.shape[0]):
      plt.subplot(4, 4, i+1)
      plt.imshow(predictions[i, :, :, 0] * 127.5 + 127.5, cmap='gray')
      plt.axis('off')
  # 3 - Save the generated images
  plt.savefig('image_at_epoch_{:04d}.png'.format(epoch))
  plt.show()

train(train_dataset, EPOCHS)
```



```
checkpoint.restore(tf.train.latest_checkpoint(checkpoint_dir))
```

```
<tensorflow.python.training.tracking.util.CheckpointLoadStatus at 0x7fa5a8329730>
```

```
# PIL is a library which may open different image file formats
import PIL
# Display a single image using the epoch number
def display_image(epoch_no):
  return PIL.Image.open('image_at_epoch_{:04d}.png'.format(epoch_no))
display_image(EPOCHS)
```

```
import glob # The glob module is used for Unix style pathname pattern expansion.
import imageio # The library that provides an easy interface to read and write a wide range

anim_file = 'dcgan.gif'

with imageio.get_writer(anim_file, mode='I') as writer:
  filenames = glob.glob('image*.png')
  filenames = sorted(filenames)
  for filename in filenames:
    image = imageio.imread(filename)
    writer.append_data(image)
  # image = imageio.imread(filename)
  # writer.append_data(image)

display.Image(open('dcgan.gif','rb').read())
```