stylegan

March 31, 2024

0.1 Setup

[ ]:
```
!pip install tensorflow_addons
```

```
Collecting tensorflow_addons
  Downloading tensorflow_addons-0.23.0-cp310-cp310-manylinux_2_17_x86_64.manylin
ux2014_x86_64.whl (611 kB)
                            611.8/611.8

kB 6.4 MB/s eta 0:00:00
Requirement already satisfied: packaging in
/usr/local/lib/python3.10/dist-packages (from tensorflow_addons) (24.0)
Collecting typeguard<3.0.0,>=2.7 (from tensorflow_addons)
  Downloading typeguard-2.13.3-py3-none-any.whl (17 kB)
Installing collected packages: typeguard, tensorflow_addons
Successfully installed tensorflow_addons-0.23.0 typeguard-2.13.3
```

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

from functools import partial

import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers
from tensorflow.keras.models import Sequential
from tensorflow_addons.layers import InstanceNormalization

import gdown
from zipfile import ZipFile
```

```
/usr/local/lib/python3.10/dist-
packages/tensorflow_addons/utils/tfa_eol_msg.py:23: UserWarning:

TensorFlow Addons (TFA) has ended development and introduction of new features.
TFA has entered a minimal maintenance and release mode until a planned end of
life in May 2024.
Please modify downstream libraries to take dependencies from other repositories
```

```
in our TensorFlow community (e.g. Keras, Keras-CV, and Keras-NLP).

For more information see: https://github.com/tensorflow/addons/issues/2807

  warnings.warn(
```

Load the dataset

```
[ ]: def log2(x):
         return int(np.log2(x))


     # we use different batch size for different resolution, so larger image size
     # could fit into GPU memory. The keys is image resolution in log2
     batch_sizes = {2: 16, 3: 16, 4: 16, 5: 16, 6: 16, 7: 8, 8: 4, 9: 2, 10: 1}
     # We adjust the train step accordingly
     train_step_ratio = {k: batch_sizes[2] / v for k, v in batch_sizes.items()}


     os.makedirs("celeba_gan")

     url = "https://drive.google.com/uc?id=1O7m1010EJjLE5QxLZiM9Fpjs7Oj6e684"
     output = "celeba_gan/data.zip"
     gdown.download(url, output, quiet=True)

     with ZipFile("celeba_gan/data.zip", "r") as zipobj:
         zipobj.extractall("celeba_gan")

     # Create a dataset from our folder, and rescale the images to the [0-1] range:

     ds_train = keras.utils.image_dataset_from_directory(
         "celeba_gan", label_mode=None, image_size=(64, 64), batch_size=32
     )




     def resize_image(res, image):
         # only downsampling, so use nearest neighbor that is faster to run
         image = tf.image.resize(
             image, (res, res), method=tf.image.ResizeMethod.NEAREST_NEIGHBOR
         )
         image = tf.cast(image, tf.float32) / 127.5 - 1.0
         return image


     def create_dataloader(res):
         batch_size = batch_sizes[log2(res)]
```

```
    dl = ds_train.map(partial(resize_image, res), num_parallel_calls=tf.data.
↪AUTOTUNE).unbatch()
    dl = dl.shuffle(200).batch(batch_size, drop_remainder=True).prefetch(1).
↪repeat()
    return dl
```

```
Found 202599 files belonging to 1 classes.
```

0.2 Utility function to display images after each epoch

[ ]:
```
def plot_images(images, log2_res, fname=""):
    scales = {2: 0.5, 3: 1, 4: 2, 5: 3, 6: 4, 7: 5, 8: 6, 9: 7, 10: 8}
    scale = scales[log2_res]

    grid_col = min(images.shape[0], int(32 // scale))
    grid_row = 1

    f, axarr = plt.subplots(
        grid_row, grid_col, figsize=(grid_col * scale, grid_row * scale)
    )

    for row in range(grid_row):
        ax = axarr if grid_row == 1 else axarr[row]
        for col in range(grid_col):
            ax[col].imshow(images[row * grid_col + col])
            ax[col].axis("off")
    plt.show()
    if fname:
        f.savefig(fname)
```

0.3 Custom Layers

The following are building blocks that will be used to construct the generators and discriminators of the StyleGAN model.

[ ]:
```
def fade_in(alpha, a, b):
    return alpha * a + (1.0 - alpha) * b


def wasserstein_loss(y_true, y_pred):
    return -tf.reduce_mean(y_true * y_pred)


def pixel_norm(x, epsilon=1e-8):
    return x / tf.math.sqrt(tf.reduce_mean(x ** 2, axis=-1, keepdims=True) +␣
↪epsilon)
```

```python
def minibatch_std(input_tensor, epsilon=1e-8):
    n, h, w, c = tf.shape(input_tensor)
    group_size = tf.minimum(4, n)
    x = tf.reshape(input_tensor, [group_size, -1, h, w, c])
    group_mean, group_var = tf.nn.moments(x, axes=(0), keepdims=False)
    group_std = tf.sqrt(group_var + epsilon)
    avg_std = tf.reduce_mean(group_std, axis=[1, 2, 3], keepdims=True)
    x = tf.tile(avg_std, [group_size, h, w, 1])
    return tf.concat([input_tensor, x], axis=-1)


class EqualizedConv(layers.Layer):
    def __init__(self, out_channels, kernel=3, gain=2, **kwargs):
        super().__init__(**kwargs)
        self.kernel = kernel
        self.out_channels = out_channels
        self.gain = gain
        self.pad = kernel != 1

    def build(self, input_shape):
        self.in_channels = input_shape[-1]
        initializer = keras.initializers.RandomNormal(mean=0.0, stddev=1.0)
        self.w = self.add_weight(
            shape=[self.kernel, self.kernel, self.in_channels, self.
↪out_channels],
            initializer=initializer,
            trainable=True,
            name="kernel",
        )
        self.b = self.add_weight(
            shape=(self.out_channels,), initializer="zeros", trainable=True,␣
↪name="bias"
        )
        fan_in = self.kernel * self.kernel * self.in_channels
        self.scale = tf.sqrt(self.gain / fan_in)

    def call(self, inputs):
        if self.pad:
            x = tf.pad(inputs, [[0, 0], [1, 1], [1, 1], [0, 0]], mode="REFLECT")
        else:
            x = inputs
        output = (
            tf.nn.conv2d(x, self.scale * self.w, strides=1, padding="VALID") +␣
↪self.b
        )
        return output
```

```python
class EqualizedDense(layers.Layer):
    def __init__(self, units, gain=2, learning_rate_multiplier=1, **kwargs):
        super().__init__(**kwargs)
        self.units = units
        self.gain = gain
        self.learning_rate_multiplier = learning_rate_multiplier

    def build(self, input_shape):
        self.in_channels = input_shape[-1]
        initializer = keras.initializers.RandomNormal(
            mean=0.0, stddev=1.0 / self.learning_rate_multiplier
        )
        self.w = self.add_weight(
            shape=[self.in_channels, self.units],
            initializer=initializer,
            trainable=True,
            name="kernel",
        )
        self.b = self.add_weight(
            shape=(self.units,), initializer="zeros", trainable=True, name="bias"
        )
        fan_in = self.in_channels
        self.scale = tf.sqrt(self.gain / fan_in)

    def call(self, inputs):
        output = tf.add(tf.matmul(inputs, self.scale * self.w), self.b)
        return output * self.learning_rate_multiplier


class AddNoise(layers.Layer):
    def build(self, input_shape):
        n, h, w, c = input_shape[0]
        initializer = keras.initializers.RandomNormal(mean=0.0, stddev=1.0)
        self.b = self.add_weight(
            shape=[1, 1, 1, c], initializer=initializer, trainable=True, name="kernel"
        )

    def call(self, inputs):
        x, noise = inputs
        output = x + self.b * noise
        return output
```

```
class AdaIN(layers.Layer):
    def __init__(self, gain=1, **kwargs):
        super().__init__(**kwargs)
        self.gain = gain

    def build(self, input_shapes):
        x_shape = input_shapes[0]
        w_shape = input_shapes[1]

        self.w_channels = w_shape[-1]
        self.x_channels = x_shape[-1]

        self.dense_1 = EqualizedDense(self.x_channels, gain=1)
        self.dense_2 = EqualizedDense(self.x_channels, gain=1)

    def call(self, inputs):
        x, w = inputs
        ys = tf.reshape(self.dense_1(w), (-1, 1, 1, self.x_channels))
        yb = tf.reshape(self.dense_2(w), (-1, 1, 1, self.x_channels))
        return ys * x + yb
```

Next we build the following:

- A model mapping to map the random noise into style code
- The generator
- The discriminator

For the generator, we build generator blocks at multiple resolutions, e.g. 4x4, 8x8, ...up to 1024x1024. We only use 4x4 in the beginning and we use progressively larger-resolution blocks as the training proceeds. Same for the discriminator.

[ ]:
```
def Mapping(num_stages, input_shape=512):
    z = layers.Input(shape=(input_shape))
    w = pixel_norm(z)
    for i in range(8):
        w = EqualizedDense(512, learning_rate_multiplier=0.01)(w)
        w = layers.LeakyReLU(0.2)(w)
    w = tf.tile(tf.expand_dims(w, 1), (1, num_stages, 1))
    return keras.Model(z, w, name="mapping")


class Generator:
    def __init__(self, start_res_log2, target_res_log2):
        self.start_res_log2 = start_res_log2
        self.target_res_log2 = target_res_log2
        self.num_stages = target_res_log2 - start_res_log2 + 1
        # list of generator blocks at increasing resolution
        self.g_blocks = []
```

```python
        # list of layers to convert g_block activation to RGB
        self.to_rgb = []
        # list of noise input of different resolutions into g_blocks
        self.noise_inputs = []
        # filter size to use at each stage, keys are log2(resolution)
        self.filter_nums = {
            0: 512,
            1: 512,
            2: 512,  # 4x4
            3: 512,  # 8x8
            4: 512,  # 16x16
            5: 512,  # 32x32
            6: 256,  # 64x64
            7: 128,  # 128x128
            8: 64,  # 256x256
            9: 32,  # 512x512
            10: 16,
        }  # 1024x1024

        start_res = 2 ** start_res_log2
        self.input_shape = (start_res, start_res, self.
↪filter_nums[start_res_log2])
        self.g_input = layers.Input(self.input_shape, name="generator_input")

        for i in range(start_res_log2, target_res_log2 + 1):
            filter_num = self.filter_nums[i]
            res = 2 ** i
            self.noise_inputs.append(
                layers.Input(shape=(res, res, 1), name=f"noise_{res}x{res}")
            )
            to_rgb = Sequential(
                [
                    layers.InputLayer(input_shape=(res, res, filter_num)),
                    EqualizedConv(3, 1, gain=1),
                ],
                name=f"to_rgb_{res}x{res}",
            )
            self.to_rgb.append(to_rgb)
            is_base = i == self.start_res_log2
            if is_base:
                input_shape = (res, res, self.filter_nums[i - 1])
            else:
                input_shape = (2 ** (i - 1), 2 ** (i - 1), self.filter_nums[i -␣
↪1])
            g_block = self.build_block(
                filter_num, res=res, input_shape=input_shape, is_base=is_base
            )
```

```
        self.g_blocks.append(g_block)

    def build_block(self, filter_num, res, input_shape, is_base):
        input_tensor = layers.Input(shape=input_shape, name=f"g_{res}")
        noise = layers.Input(shape=(res, res, 1), name=f"noise_{res}")
        w = layers.Input(shape=512)
        x = input_tensor

        if not is_base:
            x = layers.UpSampling2D((2, 2))(x)
            x = EqualizedConv(filter_num, 3)(x)

        x = AddNoise()([x, noise])
        x = layers.LeakyReLU(0.2)(x)
        x = InstanceNormalization()(x)
        x = AdaIN()([x, w])

        x = EqualizedConv(filter_num, 3)(x)
        x = AddNoise()([x, noise])
        x = layers.LeakyReLU(0.2)(x)
        x = InstanceNormalization()(x)
        x = AdaIN()([x, w])
        return keras.Model([input_tensor, w, noise], x,␣
↪name=f"genblock_{res}x{res}")

    def grow(self, res_log2):
        res = 2 ** res_log2

        num_stages = res_log2 - self.start_res_log2 + 1
        w = layers.Input(shape=(self.num_stages, 512), name="w")

        alpha = layers.Input(shape=(1), name="g_alpha")
        x = self.g_blocks[0]([self.g_input, w[:, 0], self.noise_inputs[0]])

        if num_stages == 1:
            rgb = self.to_rgb[0](x)
        else:
            for i in range(1, num_stages - 1):

                x = self.g_blocks[i]([x, w[:, i], self.noise_inputs[i]])

            old_rgb = self.to_rgb[num_stages - 2](x)
            old_rgb = layers.UpSampling2D((2, 2))(old_rgb)

            i = num_stages - 1
            x = self.g_blocks[i]([x, w[:, i], self.noise_inputs[i]])
```

```
            new_rgb = self.to_rgb[i](x)

            rgb = fade_in(alpha[0], new_rgb, old_rgb)

        return keras.Model(
            [self.g_input, w, self.noise_inputs, alpha],
            rgb,
            name=f"generator_{res}_x_{res}",
        )


class Discriminator:
    def __init__(self, start_res_log2, target_res_log2):
        self.start_res_log2 = start_res_log2
        self.target_res_log2 = target_res_log2
        self.num_stages = target_res_log2 - start_res_log2 + 1
        # filter size to use at each stage, keys are log2(resolution)
        self.filter_nums = {
            0: 512,
            1: 512,
            2: 512,  # 4x4
            3: 512,  # 8x8
            4: 512,  # 16x16
            5: 512,  # 32x32
            6: 256,  # 64x64
            7: 128,  # 128x128
            8: 64,  # 256x256
            9: 32,  # 512x512
            10: 16,
        }  # 1024x1024
        # list of discriminator blocks at increasing resolution
        self.d_blocks = []
        # list of layers to convert RGB into activation for d_blocks inputs
        self.from_rgb = []

        for res_log2 in range(self.start_res_log2, self.target_res_log2 + 1):
            res = 2 ** res_log2
            filter_num = self.filter_nums[res_log2]
            from_rgb = Sequential(
                [
                    layers.InputLayer(
                        input_shape=(res, res, 3), name=f"from_rgb_input_{res}"
                    ),
                    EqualizedConv(filter_num, 1),
                    layers.LeakyReLU(0.2),
                ],
                name=f"from_rgb_{res}",
```

```
            )

            self.from_rgb.append(from_rgb)

            input_shape = (res, res, filter_num)
            if len(self.d_blocks) == 0:
                d_block = self.build_base(filter_num, res)
            else:
                d_block = self.build_block(
                    filter_num, self.filter_nums[res_log2 - 1], res
                )

            self.d_blocks.append(d_block)

    def build_base(self, filter_num, res):
        input_tensor = layers.Input(shape=(res, res, filter_num), name=f"d_{res}")
        x = minibatch_std(input_tensor)
        x = EqualizedConv(filter_num, 3)(x)
        x = layers.LeakyReLU(0.2)(x)
        x = layers.Flatten()(x)
        x = EqualizedDense(filter_num)(x)
        x = layers.LeakyReLU(0.2)(x)
        x = EqualizedDense(1)(x)
        return keras.Model(input_tensor, x, name=f"d_{res}")

    def build_block(self, filter_num_1, filter_num_2, res):
        input_tensor = layers.Input(shape=(res, res, filter_num_1), name=f"d_{res}")
        x = EqualizedConv(filter_num_1, 3)(input_tensor)
        x = layers.LeakyReLU(0.2)(x)
        x = EqualizedConv(filter_num_2)(x)
        x = layers.LeakyReLU(0.2)(x)
        x = layers.AveragePooling2D((2, 2))(x)
        return keras.Model(input_tensor, x, name=f"d_{res}")

    def grow(self, res_log2):
        res = 2 ** res_log2
        idx = res_log2 - self.start_res_log2
        alpha = layers.Input(shape=(1), name="d_alpha")
        input_image = layers.Input(shape=(res, res, 3), name="input_image")
        x = self.from_rgb[idx](input_image)
        x = self.d_blocks[idx](x)
        if idx > 0:
            idx -= 1
            downsized_image = layers.AveragePooling2D((2, 2))(input_image)
            y = self.from_rgb[idx](downsized_image)
```

```
            x = fade_in(alpha[0], x, y)

            for i in range(idx, -1, -1):
                x = self.d_blocks[i](x)
        return keras.Model([input_image, alpha], x,␣
↪name=f"discriminator_{res}_x_{res}")
```

0.4 Build StyleGAN with custom train step

[ ]:
```
class StyleGAN(tf.keras.Model):
    def __init__(self, z_dim=512, target_res=64, start_res=4):
        super().__init__()
        self.z_dim = z_dim

        self.target_res_log2 = log2(target_res)
        self.start_res_log2 = log2(start_res)
        self.current_res_log2 = self.target_res_log2
        self.num_stages = self.target_res_log2 - self.start_res_log2 + 1

        self.alpha = tf.Variable(1.0, dtype=tf.float32, trainable=False,␣
↪name="alpha")

        self.mapping = Mapping(num_stages=self.num_stages)
        self.d_builder = Discriminator(self.start_res_log2, self.
↪target_res_log2)
        self.g_builder = Generator(self.start_res_log2, self.target_res_log2)
        self.g_input_shape = self.g_builder.input_shape

        self.phase = None
        self.train_step_counter = tf.Variable(0, dtype=tf.int32,␣
↪trainable=False)

        self.loss_weights = {"gradient_penalty": 10, "drift": 0.001}

    def grow_model(self, res):
        tf.keras.backend.clear_session()
        res_log2 = log2(res)
        self.generator = self.g_builder.grow(res_log2)
        self.discriminator = self.d_builder.grow(res_log2)
        self.current_res_log2 = res_log2
        print(f"\nModel resolution:{res}x{res}")

    def compile(
        self, steps_per_epoch, phase, res, d_optimizer, g_optimizer, *args,␣
↪**kwargs
    ):
```

```
        self.loss_weights = kwargs.pop("loss_weights", self.loss_weights)
        self.steps_per_epoch = steps_per_epoch
        if res != 2 ** self.current_res_log2:
            self.grow_model(res)
            self.d_optimizer = d_optimizer
            self.g_optimizer = g_optimizer

        self.train_step_counter.assign(0)
        self.phase = phase
        self.d_loss_metric = keras.metrics.Mean(name="d_loss")
        self.g_loss_metric = keras.metrics.Mean(name="g_loss")
        super().compile(*args, **kwargs)

    @property
    def metrics(self):
        return [self.d_loss_metric, self.g_loss_metric]

    def generate_noise(self, batch_size):
        noise = [
            tf.random.normal((batch_size, 2 ** res, 2 ** res, 1))
            for res in range(self.start_res_log2, self.target_res_log2 + 1)
        ]
        return noise

    def gradient_loss(self, grad):
        loss = tf.square(grad)
        loss = tf.reduce_sum(loss, axis=tf.range(1, tf.size(tf.shape(loss))))
        loss = tf.sqrt(loss)
        loss = tf.reduce_mean(tf.square(loss - 1))
        return loss

    def train_step(self, real_images):

        self.train_step_counter.assign_add(1)

        if self.phase == "TRANSITION":
            self.alpha.assign(
                tf.cast(self.train_step_counter / self.steps_per_epoch, tf.
↪float32)
            )
        elif self.phase == "STABLE":
            self.alpha.assign(1.0)
        else:
            raise NotImplementedError
        alpha = tf.expand_dims(self.alpha, 0)
        batch_size = tf.shape(real_images)[0]
        real_labels = tf.ones(batch_size)
```

```
        fake_labels = -tf.ones(batch_size)

        z = tf.random.normal((batch_size, self.z_dim))
        const_input = tf.ones(tuple([batch_size] + list(self.g_input_shape)))
        noise = self.generate_noise(batch_size)

        # generator
        with tf.GradientTape() as g_tape:
            w = self.mapping(z)
            fake_images = self.generator([const_input, w, noise, alpha])
            pred_fake = self.discriminator([fake_images, alpha])
            g_loss = wasserstein_loss(real_labels, pred_fake)

            trainable_weights = (
                self.mapping.trainable_weights + self.generator.trainable_weights
            )
            gradients = g_tape.gradient(g_loss, trainable_weights)
            self.g_optimizer.apply_gradients(zip(gradients, trainable_weights))

        # discriminator
        with tf.GradientTape() as gradient_tape, tf.GradientTape() as total_tape:
            # forward pass
            pred_fake = self.discriminator([fake_images, alpha])
            pred_real = self.discriminator([real_images, alpha])

            epsilon = tf.random.uniform((batch_size, 1, 1, 1))
            interpolates = epsilon * real_images + (1 - epsilon) * fake_images
            gradient_tape.watch(interpolates)
            pred_fake_grad = self.discriminator([interpolates, alpha])

            # calculate losses
            loss_fake = wasserstein_loss(fake_labels, pred_fake)
            loss_real = wasserstein_loss(real_labels, pred_real)
            loss_fake_grad = wasserstein_loss(fake_labels, pred_fake_grad)

            # gradient penalty
            gradients_fake = gradient_tape.gradient(loss_fake_grad, [interpolates])
            gradient_penalty = self.loss_weights[
                "gradient_penalty"
            ] * self.gradient_loss(gradients_fake)

            # drift loss
            all_pred = tf.concat([pred_fake, pred_real], axis=0)
```

```python
            drift_loss = self.loss_weights["drift"] * tf.reduce_mean(all_pred␣
↪** 2)

            d_loss = loss_fake + loss_real + gradient_penalty + drift_loss

            gradients = total_tape.gradient(
                d_loss, self.discriminator.trainable_weights
            )
            self.d_optimizer.apply_gradients(
                zip(gradients, self.discriminator.trainable_weights)
            )

        # Update metrics
        self.d_loss_metric.update_state(d_loss)
        self.g_loss_metric.update_state(g_loss)
        return {
            "d_loss": self.d_loss_metric.result(),
            "g_loss": self.g_loss_metric.result(),
        }

    def call(self, inputs: dict()):
        style_code = inputs.get("style_code", None)
        z = inputs.get("z", None)
        noise = inputs.get("noise", None)
        batch_size = inputs.get("batch_size", 1)
        alpha = inputs.get("alpha", 1.0)
        alpha = tf.expand_dims(alpha, 0)
        if style_code is None:
            if z is None:
                z = tf.random.normal((batch_size, self.z_dim))
            style_code = self.mapping(z)

        if noise is None:
            noise = self.generate_noise(batch_size)

        # self.alpha.assign(alpha)

        const_input = tf.ones(tuple([batch_size] + list(self.g_input_shape)))
        images = self.generator([const_input, style_code, noise, alpha])
        images = np.clip((images * 0.5 + 0.5) * 255, 0, 255).astype(np.uint8)

        return images
```

0.5 Training

We first build the StyleGAN at smallest resolution, such as 4x4 or 8x8. Then we progressively grow the model to higher resolution by appending new generator and discriminator blocks.

[ ]:
```
START_RES = 4
TARGET_RES = 128

style_gan = StyleGAN(start_res=START_RES, target_res=TARGET_RES)
```

The training for each new resolution happens in two phases - "transition" and "stable". In the transition phase, the features from the previous resolution are mixed with the current resolution. This allows for a smoother transition when scaling up. We use each epoch in `model.fit()` as a phase.

[ ]:
```
def train(
    start_res=START_RES,
    target_res=TARGET_RES,
    steps_per_epoch=5000,
    display_images=True,
):
    opt_cfg = {"learning_rate": 1e-3, "beta_1": 0.0, "beta_2": 0.99, "epsilon":␣
 ↪1e-8}

    val_batch_size = 16
    val_z = tf.random.normal((val_batch_size, style_gan.z_dim))
    val_noise = style_gan.generate_noise(val_batch_size)

    start_res_log2 = int(np.log2(start_res))
    target_res_log2 = int(np.log2(target_res))

    for res_log2 in range(start_res_log2, target_res_log2 + 1):
        res = 2 ** res_log2
        for phase in ["TRANSITION", "STABLE"]:
            if res == start_res and phase == "TRANSITION":
                continue

            train_dl = create_dataloader(res)

            steps = int(train_step_ratio[res_log2] * steps_per_epoch)

            style_gan.compile(
                d_optimizer=tf.keras.optimizers.legacy.Adam(**opt_cfg),
                g_optimizer=tf.keras.optimizers.legacy.Adam(**opt_cfg),
                loss_weights={"gradient_penalty": 10, "drift": 0.001},
                steps_per_epoch=steps,
                res=res,
                phase=phase,
                run_eagerly=False,
            )

            prefix = f"res_{res}x{res}_{style_gan.phase}"
```

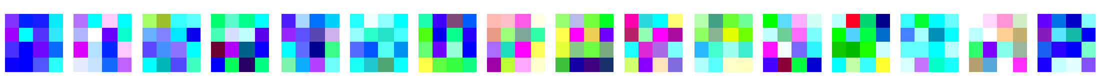
```
            ckpt_cb = keras.callbacks.ModelCheckpoint(
                f"checkpoints/stylegan_{res}x{res}.ckpt",
                save_weights_only=True,
                verbose=0,
            )
            print(phase)
            style_gan.fit(
                train_dl, epochs=1, steps_per_epoch=steps, callbacks=[ckpt_cb]
            )

            if display_images:
                images = style_gan({"z": val_z, "noise": val_noise, "alpha": 1.
↪0})
                plot_images(images, res_log2)
```

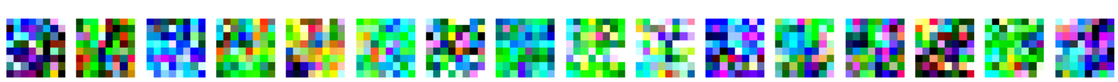
StyleGAN can take a long time to train, in the code below, a small `steps_per_epoch` value of 1 is used to sanity-check the code is working alright. In practice, a larger `steps_per_epoch` value (over 10000) is required to get decent results.

[ ]:
```
train(start_res=4, target_res=16, steps_per_epoch=1, display_images=True)
```

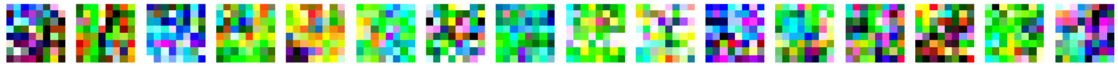
```
Model resolution:4x4
STABLE
1/1 [==============================] - 9s 9s/step - d_loss: 0.5178 - g_loss:
3.7827
```



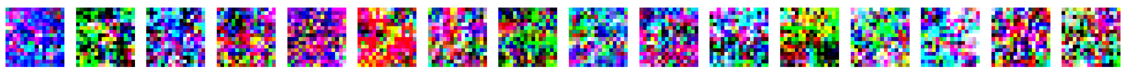
```
Model resolution:8x8
TRANSITION
1/1 [==============================] - 8s 8s/step - d_loss: 4.8857 - g_loss:
2.2148
```



```
STABLE
1/1 [==============================] - 4s 4s/step - d_loss: 2.5059 - g_loss:
4.7551
```



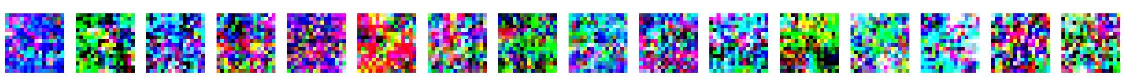
```
Model resolution:16x16
TRANSITION
1/1 [==============================] - 10s 10s/step - d_loss: 2.0437 - g_loss:
9.8106
```



```
STABLE

WARNING:tensorflow:5 out of the last 5 calls to <function
Model.make_train_function.<locals>.train_function at 0x7c8ffb9ba050> triggered
tf.function retracing. Tracing is expensive and the excessive number of tracings
could be due to (1) creating @tf.function repeatedly in a loop, (2) passing
tensors with different shapes, (3) passing Python objects instead of tensors.
For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has reduce_retracing=True option that can avoid unnecessary
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.

1/1 [==============================] - 6s 6s/step - d_loss: -0.9936 - g_loss:
14.7816
```



0.6 Results

We can now run some inference using pre-trained 64x64 checkpoints. In general, the image fidelity increases with the resolution. You can try to train this StyleGAN to resolutions above 128x128 with the CelebA HQ dataset.

[ ]:
```
url = "https://github.com/soon-yau/stylegan_keras/releases/download/
 ↪keras_example_v1.0/stylegan_128x128.ckpt.zip"

weights_path = keras.utils.get_file(
    "stylegan_128x128.ckpt.zip",
```

```
    url,
    extract=True,
    cache_dir=os.path.abspath("."),
    cache_subdir="pretrained",
)

style_gan.grow_model(128)
style_gan.load_weights(os.path.join("pretrained/stylegan_128x128.ckpt"))

tf.random.set_seed(196)
batch_size = 2
z = tf.random.normal((batch_size, style_gan.z_dim))
w = style_gan.mapping(z)
noise = style_gan.generate_noise(batch_size=batch_size)
images = style_gan({"style_code": w, "noise": noise, "alpha": 1.0})
plot_images(images, 5)
```

```
Downloading data from https://github.com/soon-yau/stylegan_keras/releases/downlo
ad/keras_example_v1.0/stylegan_128x128.ckpt.zip
540534982/540534982 [==============================] - 10s 0us/step

Model resolution:128x128
```


0.7 Style Mixing

We can also mix styles from two images to create a new image.

[ ]:
```
alpha = 0.4
w_mix = np.expand_dims(alpha * w[0] + (1 - alpha) * w[1], 0)
noise_a = [np.expand_dims(n[0], 0) for n in noise]
mix_images = style_gan({"style_code": w_mix, "noise": noise_a})
image_row = np.hstack([images[0], images[1], mix_images[0]])
```

```
plt.figure(figsize=(9, 3))
plt.imshow(image_row)
plt.axis("off")
```

[ ]: (-0.5, 383.5, 127.5, -0.5)