This is a companion notebook for the book Deep Learning with Python, Second Edition. For readability, it only contains runnable code blocks and section titles, and omits everything else in the book: text paragraphs, figures, and pseudocode.

If you want to be able to follow what's going on, I recommend reading the notebook side by side with your copy of the book.

This notebook was generated for TensorFlow 2.6.

Neural style transfer

The content loss

The style loss

Neural style transfer in Keras

Getting the style and content images

```
from tensorflow import keras

base_image_path = keras.utils.get_file(
    "sf.jpg", origin="https://img-datasets.s3.amazonaws.com/sf.jpg")
style_reference_image_path = keras.utils.get_file(
    "starry_night.jpg", origin="https://img-datasets.s3.amazonaws.com/starry_night.jpg")

original_width, original_height = keras.utils.load_img(base_image_path).size
img_height = 400
img_width = round(original_width * img_height / original_height)
```

Auxiliary functions

```
import numpy as np

def preprocess_image(image_path):
    img = keras.utils.load_img(
        image_path, target_size=(img_height, img_width))
    img = keras.utils.img_to_array(img)
    img = np.expand_dims(img, axis=0)
    img = keras.applications.vgg19.preprocess_input(img)
    return img

def deprocess_image(img):
    img = img.reshape((img_height, img_width, 3))
    img[:, :, 0] += 103.939
    img[:, :, 1] += 116.779
    img[:, :, 2] += 123.68
    img = img[:, :, ::-1]
    img = np.clip(img, 0, 255).astype("uint8")
    return img
```

Using a pretrained VGG19 model to create a feature extractor

```
model = keras.applications.vgg19.VGG19(weights="imagenet", include_top=False)

outputs_dict = dict([(layer.name, layer.output) for layer in model.layers])
feature_extractor = keras.Model(inputs=model.inputs, outputs=outputs_dict)
```

Content loss

```
def content_loss(base_img, combination_img):
    return tf.reduce_sum(tf.square(combination_img - base_img))
```

Style loss

```
def gram_matrix(x):
    x = tf.transpose(x, (2, 0, 1))
    features = tf.reshape(x, (tf.shape(x)[0], -1))
    gram = tf.matmul(features, tf.transpose(features))
    return gram

def style_loss(style_img, combination_img):
    S = gram_matrix(style_img)
    C = gram_matrix(combination_img)
    channels = 3
    size = img_height * img_width
    return tf.reduce_sum(tf.square(S - C)) / (4.0 * (channels ** 2) * (size ** 2))
```

Total variation loss

```
def total_variation_loss(x):
    a = tf.square(
        x[:, : img_height - 1, : img_width - 1, :] - x[:, 1:, : img_width - 1, :]
    )
    b = tf.square(
        x[:, : img_height - 1, : img_width - 1, :] - x[:, : img_height - 1, 1:, :]
    )
    return tf.reduce_sum(tf.pow(a + b, 1.25))
```

Defining the final loss that you'll minimize

```
style_layer_names = [
    "block1_conv1",
    "block2_conv1",
    "block3_conv1",
    "block4_conv1",
    "block5_conv1",
]
content_layer_name = "block5_conv2"
total_variation_weight = 1e-6
style_weight = 1e-6
content_weight = 2.5e-8

def compute_loss(combination_image, base_image, style_reference_image):
    input_tensor = tf.concat(
        [base_image, style_reference_image, combination_image], axis=0
    )
    features = feature_extractor(input_tensor)
    loss = tf.zeros(shape=())
    layer_features = features[content_layer_name]
    base_image_features = layer_features[0, :, :, :]
    combination_features = layer_features[2, :, :, :]
    loss = loss + content_weight * content_loss(
        base_image_features, combination_features
    )
    for layer_name in style_layer_names:
        layer_features = features[layer_name]
        style_reference_features = layer_features[1, :, :, :]
        combination_features = layer_features[2, :, :, :]
        style_loss_value = style_loss(
          style_reference_features, combination_features)
        loss += (style_weight / len(style_layer_names)) * style_loss_value

    loss += total_variation_weight * total_variation_loss(combination_image)
    return loss
```

Setting up the gradient-descent process

```
import tensorflow as tf

@tf.function
def compute_loss_and_grads(combination_image, base_image, style_reference_image):
    with tf.GradientTape() as tape:
        loss = compute_loss(combination_image, base_image, style_reference_image)
    grads = tape.gradient(loss, combination_image)
    return loss, grads

optimizer = keras.optimizers.SGD(
    keras.optimizers.schedules.ExponentialDecay(
        initial_learning_rate=100.0, decay_steps=100, decay_rate=0.96
    )
)
```

```
base_image = preprocess_image(base_image_path)
style_reference_image = preprocess_image(style_reference_image_path)
combination_image = tf.Variable(preprocess_image(base_image_path))

iterations = 4000
for i in range(1, iterations + 1):
    loss, grads = compute_loss_and_grads(
        combination_image, base_image, style_reference_image
    )
    optimizer.apply_gradients([(grads, combination_image)])
    if i % 100 == 0:
        print(f"Iteration {i}: loss={loss:.2f}")
        img = deprocess_image(combination_image.numpy())
        fname = f"combination_image_at_iteration_{i}.png"
        keras.utils.save_img(fname, img)
```

Wrapping up