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.

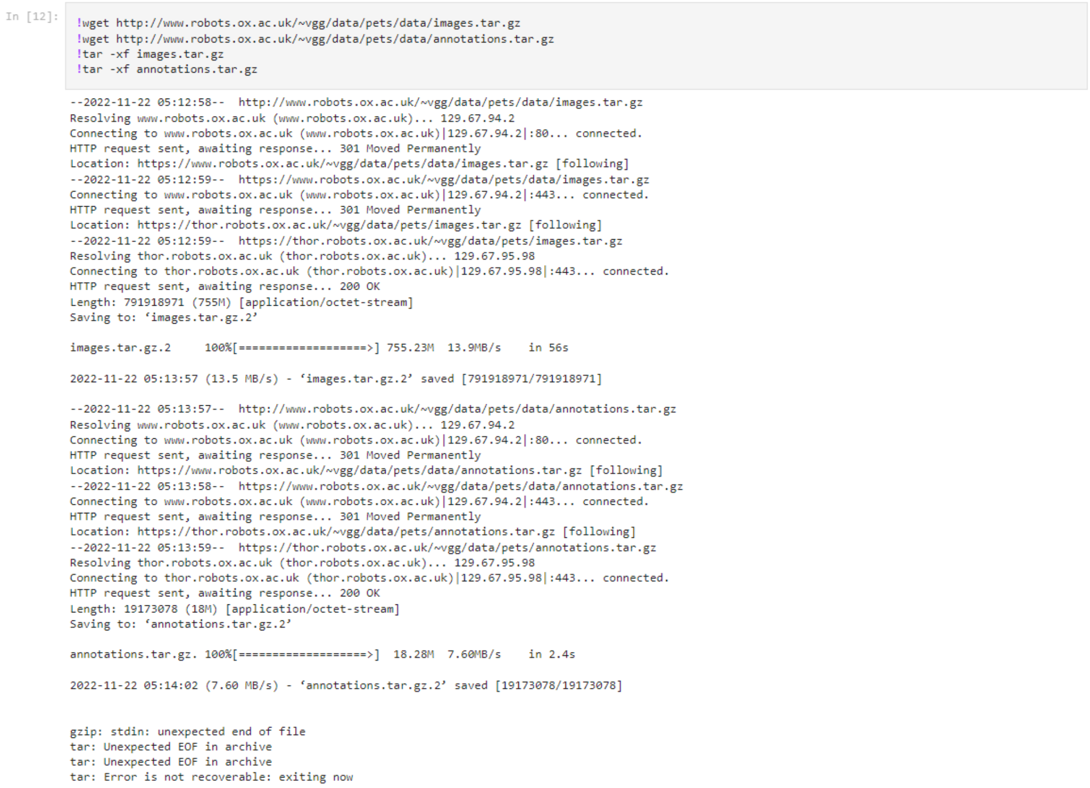
If you want to be able to follow what's going on, I recommend reading the notebook side by side with your copy of the book.

This notebook was generated for TensorFlow 2.6.

Advanced deep learning for computer vision

Three essential computer vision tasks

An image segmentation example



In [12]:

```
!wget http://www.robots.ox.ac.uk/~vgg/data/pets/data/images.tar.gz
!wget http://www.robots.ox.ac.uk/~vgg/data/pets/data/annotations.tar.gz
!tar -xf images.tar.gz
!tar -xf annotations.tar.gz
```

```
--2022-11-22 05:12:58--  http://www.robots.ox.ac.uk/~vgg/data/pets/data/images.tar.gz
Resolving www.robots.ox.ac.uk (www.robots.ox.ac.uk)... 129.67.94.2
Connecting to www.robots.ox.ac.uk (www.robots.ox.ac.uk)|129.67.94.2|:80... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: https://www.robots.ox.ac.uk/~vgg/data/pets/data/images.tar.gz [following]
--2022-11-22 05:12:59--  https://www.robots.ox.ac.uk/~vgg/data/pets/data/images.tar.gz
Connecting to www.robots.ox.ac.uk (www.robots.ox.ac.uk)|129.67.94.2|:443... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: https://thor.robots.ox.ac.uk/~vgg/data/pets/images.tar.gz [following]
--2022-11-22 05:12:59--  https://thor.robots.ox.ac.uk/~vgg/data/pets/images.tar.gz
Resolving thor.robots.ox.ac.uk (thor.robots.ox.ac.uk)... 129.67.95.98
Connecting to thor.robots.ox.ac.uk (thor.robots.ox.ac.uk)|129.67.95.98|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 791918971 (755M) [application/octet-stream]
Saving to: ‘images.tar.gz.2’

images.tar.gz.2     100%[===================>] 755.23M  13.9MB/s    in 56s

2022-11-22 05:13:57 (13.5 MB/s) - ‘images.tar.gz.2’ saved [791918971/791918971]

--2022-11-22 05:13:57--  http://www.robots.ox.ac.uk/~vgg/data/pets/data/annotations.tar.gz
Resolving www.robots.ox.ac.uk (www.robots.ox.ac.uk)... 129.67.94.2
Connecting to www.robots.ox.ac.uk (www.robots.ox.ac.uk)|129.67.94.2|:80... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: https://www.robots.ox.ac.uk/~vgg/data/pets/data/annotations.tar.gz [following]
--2022-11-22 05:13:58--  https://www.robots.ox.ac.uk/~vgg/data/pets/data/annotations.tar.gz
Connecting to www.robots.ox.ac.uk (www.robots.ox.ac.uk)|129.67.94.2|:443... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: https://thor.robots.ox.ac.uk/~vgg/data/pets/annotations.tar.gz [following]
--2022-11-22 05:13:59--  https://thor.robots.ox.ac.uk/~vgg/data/pets/annotations.tar.gz
Resolving thor.robots.ox.ac.uk (thor.robots.ox.ac.uk)... 129.67.95.98
Connecting to thor.robots.ox.ac.uk (thor.robots.ox.ac.uk)|129.67.95.98|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 19173078 (18M) [application/octet-stream]
Saving to: ‘annotations.tar.gz.2’

annotations.tar.gz. 100%[===================>]  18.28M  7.60MB/s    in 2.4s

2022-11-22 05:14:02 (7.60 MB/s) - ‘annotations.tar.gz.2’ saved [19173078/19173078]


gzip: stdin: unexpected end of file
tar: Unexpected EOF in archive
tar: Unexpected EOF in archive
tar: Error is not recoverable: exiting now
```

In [13]:

```
import os

input_dir = "images/"
target_dir = "annotations/trimaps/"

input_img_paths = sorted(
    [os.path.join(input_dir, fname)
     for fname in os.listdir(input_dir)
     if fname.endswith(".jpg")])
target_paths = sorted(
    [os.path.join(target_dir, fname)
     for fname in os.listdir(target_dir)
     if fname.endswith(".png") and not fname.startswith(".")])
```

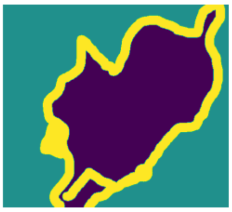
In [14]:

```
import matplotlib.pyplot as plt
from tensorflow.keras.utils import load_img, img_to_array

plt.axis("off")
plt.imshow(load_img(input_img_paths[9]))
```

Out[14]:

In [15]:

```
def display_target(target_array):
    normalized_array = (target_array.astype("uint8") - 1) * 127
    plt.axis("off")
    plt.imshow(normalized_array[:, :, 0])

img = img_to_array(load_img(target_paths[9], color_mode="grayscale"))
display_target(img)
```



In [17]:

```
import numpy as np
import random

from PIL import ImageFile
ImageFile.LOAD_TRUNCATED_IMAGES = True

img_size = (200, 200)
num_imgs = len(input_img_paths)

random.Random(1337).shuffle(input_img_paths)
random.Random(1337).shuffle(target_paths)

def path_to_input_image(path):
    return img_to_array(load_img(path, target_size=img_size))

def path_to_target(path):
    img = img_to_array(
        load_img(path, target_size=img_size, color_mode="grayscale"))
    img = img.astype("uint8") - 1
    return img

input_imgs = np.zeros((num_imgs,) + img_size + (3,), dtype="float32")
targets = np.zeros((num_imgs,) + img_size + (1,), dtype="uint8")
for i in range(num_imgs):
    input_imgs[i] = path_to_input_image(input_img_paths[i])
    targets[i] = path_to_target(target_paths[i])

num_val_samples = 1000
train_input_imgs = input_imgs[:-num_val_samples]
train_targets = targets[:-num_val_samples]
val_input_imgs = input_imgs[-num_val_samples:]
val_targets = targets[-num_val_samples:]
```

In [18]:

```python
from tensorflow import keras
from tensorflow.keras import layers

def get_model(img_size, num_classes):
    inputs = keras.Input(shape=img_size + (3,))
    x = layers.Rescaling(1./255)(inputs)

    x = layers.Conv2D(64, 3, strides=2, activation="relu", padding="same")(x)
    x = layers.Conv2D(64, 3, activation="relu", padding="same")(x)
    x = layers.Conv2D(128, 3, strides=2, activation="relu", padding="same")(x)
    x = layers.Conv2D(128, 3, activation="relu", padding="same")(x)
    x = layers.Conv2D(256, 3, strides=2, padding="same", activation="relu")(x)
    x = layers.Conv2D(256, 3, activation="relu", padding="same")(x)

    x = layers.Conv2DTranspose(256, 3, activation="relu", padding="same")(x)
    x = layers.Conv2DTranspose(256, 3, activation="relu", padding="same", strides=2)(x)
    x = layers.Conv2DTranspose(128, 3, activation="relu", padding="same")(x)
    x = layers.Conv2DTranspose(128, 3, activation="relu", padding="same", strides=2)(x)
    x = layers.Conv2DTranspose(64, 3, activation="relu", padding="same")(x)
    x = layers.Conv2DTranspose(64, 3, activation="relu", padding="same", strides=2)(x)

    outputs = layers.Conv2D(num_classes, 3, activation="softmax", padding="same")(x)

    model = keras.Model(inputs, outputs)
    return model

model = get_model(img_size=img_size, num_classes=3)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_1 (InputLayer)        [(None, 200, 200, 3)]     0         
                                                                 
 rescaling (Rescaling)       (None, 200, 200, 3)       0         
                                                                 
 conv2d (Conv2D)             (None, 100, 100, 64)      1792      
                                                                 
 conv2d_1 (Conv2D)           (None, 100, 100, 64)      36928     
                                                                 
 conv2d_2 (Conv2D)           (None, 50, 50, 128)       73856     
                                                                 
 conv2d_3 (Conv2D)           (None, 50, 50, 128)       147584    
                                                                 
 conv2d_4 (Conv2D)           (None, 25, 25, 256)       295168    
                                                                 
 conv2d_5 (Conv2D)           (None, 25, 25, 256)       590080    
                                                                 
 conv2d_transpose (Conv2DTra  (None, 25, 25, 256)      590080    
 nspose)                                                         
                                                                 
 conv2d_transpose_1 (Conv2DT  (None, 50, 50, 256)      590080    
 ranspose)                                                       
                                                                 
 conv2d_transpose_2 (Conv2DT  (None, 50, 50, 128)      295040    
 ranspose)                                                       
                                                                 
 conv2d_transpose_3 (Conv2DT  (None, 100, 100, 128)    147584    
 ranspose)                                                       
                                                                 
 conv2d_transpose_4 (Conv2DT  (None, 100, 100, 64)     73792     
 ranspose)                                                       
                                                                 
 conv2d_transpose_5 (Conv2DT  (None, 200, 200, 64)     36928     
 ranspose)                                                       
                                                                 
 conv2d_6 (Conv2D)           (None, 200, 200, 3)       1731      
                                                                 
=================================================================
Total params: 2,880,643
Trainable params: 2,880,643
Non-trainable params: 0
_________________________________________________________________
```

In [19]:

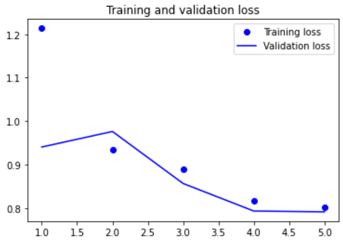
```python
model.compile(optimizer="rmsprop", loss="sparse_categorical_crossentropy")

callbacks = [
    keras.callbacks.ModelCheckpoint("oxford_segmentation.keras",
                                    save_best_only=True)
]

history = model.fit(train_input_imgs, train_targets,
                    epochs=5,
                    callbacks=callbacks,
                    batch_size=64,
                    validation_data=(val_input_imgs, val_targets))
```

```
Epoch 1/5
55/55 [==============================] - 54s 689ms/step - loss: 1.2138 - val_loss: 0.9405
Epoch 2/5
55/55 [==============================] - 33s 607ms/step - loss: 0.9345 - val_loss: 0.9763
Epoch 3/5
55/55 [==============================] - 34s 624ms/step - loss: 0.8901 - val_loss: 0.8566
Epoch 4/5
55/55 [==============================] - 36s 649ms/step - loss: 0.8177 - val_loss: 0.7932
Epoch 5/5
55/55 [==============================] - 35s 640ms/step - loss: 0.8016 - val_loss: 0.7913
```

In [20]:

```
epochs = range(1, len(history.history["loss"]) + 1)
loss = history.history["loss"]
val_loss = history.history["val_loss"]
plt.figure()
plt.plot(epochs, loss, "bo", label="Training loss")
plt.plot(epochs, val_loss, "b", label="Validation loss")
plt.title("Training and validation loss")
plt.legend()
```

Out[20]:



In [21]:

```
from tensorflow.keras.utils import array_to_img

model = keras.models.load_model("oxford_segmentation.keras")

i = 4
test_image = val_input_imgs[i]
plt.axis("off")
plt.imshow(array_to_img(test_image))

mask = model.predict(np.expand_dims(test_image, 0))[0]

def display_mask(pred):
    mask = np.argmax(pred, axis=-1)
    mask *= 127
    plt.axis("off")
    plt.imshow(mask)

display_mask(mask)
```

```
1/1 [==============================] - 1s 732ms/step
```