Streaming output truncated to the last 5000 lines.

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Q1. Consider the Cats & Dogs example. Start initially with a training sample of 1000, a validation sample of 500, and a test sample of 500 (like in the text). Use any technique to reduce overfitting and improve performance in developing a network that you train from scratch. What performance did you achieve?

Data preprocessing

```
In [10]: # Managing the file directory; Splitting the file system into train(1000), test(500)
from tensorflow.keras.utils import image_dataset_from_directory

training_datasets = image_dataset_from_directory(
    new_base_dir / "train",
    image_size=(180, 180),
    batch_size=32)

valid_datasets = image_dataset_from_directory(
    new_base_dir / "validation",
    image_size=(180, 180),
    batch_size=32)

testing_datasets = image_dataset_from_directory(
    new_base_dir / "test",
    image_size=(180, 180),
    batch_size=32)
```

Found 2000 files belonging to 2 classes. Found 1000 files belonging to 2 classes. Found 1000 files belonging to 2 classes.

Create a datset instance from NumPy array of random numbers of 1000 samples and each sample of vector size 16

```
In [11]: import numpy as np
import tensorflow as tf
```

```
random_numbers = np.random.normal(size=(1000, 16))
dataset = tf.data.Dataset.from_tensor_slices(random_numbers)
```

creating the data into batches of size 32

```
for i, element in enumerate(dataset):
In [12]:
              print(element.shape)
              if i >= 2:
                  break
          (16,)
          (16,)
          (16,)
In [13]: batched_dataset = dataset.batch(32)
          for i, element in enumerate(batched_dataset):
              print(element.shape)
              if i >= 2:
                  break
          (32, 16)
          (32, 16)
          (32, 16)
In [14]: reshaped_dataset = dataset.map(lambda x: tf.reshape(x, (4, 4)))
          for i, element in enumerate(reshaped_dataset):
              print(element.shape)
              if i >= 2:
                  break
          (4, 4)
          (4, 4)
          (4, 4)
         Display the shapes of the data and labels by the Dataset
In [15]:
         for data_batch, labels_batch in training_datasets:
              print("data batch shape:", data_batch.shape)
              print("labels batch shape:", labels_batch.shape)
              break
          data batch shape: (32, 180, 180, 3)
         labels batch shape: (32,)
```

Incorporating a small convnet for dogs vs. cats classification

```
In [16]: from tensorflow import keras
    from tensorflow.keras import layers

inputs = keras.Input(shape=(180, 180, 3))
    a = layers.Rescaling(1./255)(inputs)
    a = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(a)
    a = layers.MaxPooling2D(pool_size=2)(a)
    a = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(a)
    a = layers.MaxPooling2D(pool_size=2)(a)
    a = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(a)
    a = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(a)
    a = layers.MaxPooling2D(pool_size=2)(a)
    a = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(a)
    a = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(a)
```

Build the model

summary of the model

In [18]: model.summary()

Model: "model"

Layer (type)	Output Shape	Param #
input_1 (InputLayer)		0
rescaling (Rescaling)	(None, 180, 180, 3)	0
conv2d (Conv2D)	(None, 178, 178, 32)	896
<pre>max_pooling2d (MaxPooling2 D)</pre>	(None, 89, 89, 32)	0
conv2d_1 (Conv2D)	(None, 87, 87, 64)	18496
<pre>max_pooling2d_1 (MaxPoolin g2D)</pre>	(None, 43, 43, 64)	0
conv2d_2 (Conv2D)	(None, 41, 41, 128)	73856
<pre>max_pooling2d_2 (MaxPoolin g2D)</pre>	(None, 20, 20, 128)	0
conv2d_3 (Conv2D)	(None, 18, 18, 256)	295168
<pre>max_pooling2d_3 (MaxPoolin g2D)</pre>	(None, 9, 9, 256)	0
conv2d_4 (Conv2D)	(None, 7, 7, 256)	590080
flatten (Flatten)	(None, 12544)	0
dropout (Dropout)	(None, 12544)	0
dense (Dense)	(None, 1)	12545

```
In [19]: from keras.callbacks import ModelCheckpoint, EarlyStopping

callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch.keras",
        save_best_only=True,
        monitor="val_loss")
]
```

```
history = model.fit(
    training_datasets,
    epochs=30,
    validation_data=valid_datasets,
    callbacks=callbacks)
```

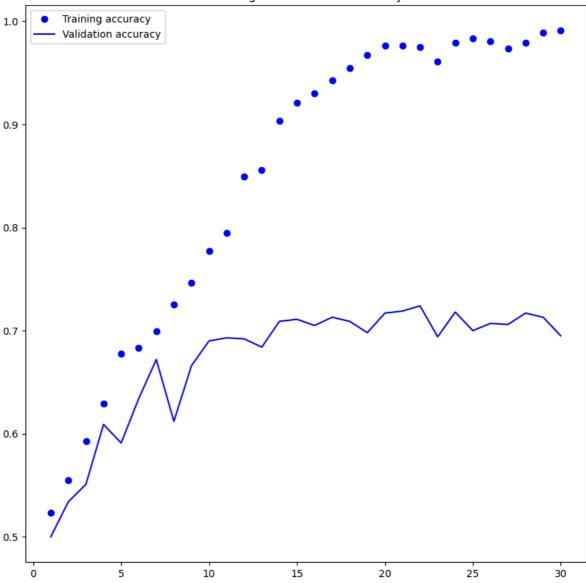
```
Epoch 1/30
63/63 [============] - 9s 32ms/step - loss: 0.6953 - accuracy:
0.5230 - val_loss: 0.6936 - val_accuracy: 0.5000
Epoch 2/30
63/63 [============] - 1s 17ms/step - loss: 0.6858 - accuracy:
0.5550 - val loss: 0.6854 - val accuracy: 0.5340
63/63 [============] - 1s 16ms/step - loss: 0.6665 - accuracy:
0.5930 - val_loss: 0.6841 - val_accuracy: 0.5510
Epoch 4/30
63/63 [============] - 1s 15ms/step - loss: 0.6508 - accuracy:
0.6295 - val_loss: 0.6956 - val_accuracy: 0.6090
Epoch 5/30
63/63 [============] - 1s 16ms/step - loss: 0.6152 - accuracy:
0.6775 - val loss: 0.6670 - val accuracy: 0.5910
Epoch 6/30
0.6830 - val_loss: 0.6562 - val_accuracy: 0.6340
Epoch 7/30
63/63 [============] - 1s 16ms/step - loss: 0.5733 - accuracy:
0.6995 - val_loss: 0.6466 - val_accuracy: 0.6720
Epoch 8/30
0.7255 - val loss: 0.6434 - val accuracy: 0.6120
Epoch 9/30
63/63 [============] - 1s 15ms/step - loss: 0.5162 - accuracy:
0.7465 - val loss: 0.6509 - val accuracy: 0.6660
Epoch 10/30
63/63 [============] - 1s 16ms/step - loss: 0.4565 - accuracy:
0.7775 - val_loss: 0.6722 - val_accuracy: 0.6900
Epoch 11/30
63/63 [============ - 1s 17ms/step - loss: 0.4178 - accuracy:
0.7945 - val loss: 0.6197 - val accuracy: 0.6930
Epoch 12/30
63/63 [============] - 1s 15ms/step - loss: 0.3301 - accuracy:
0.8495 - val_loss: 0.7559 - val_accuracy: 0.6920
Epoch 13/30
63/63 [=============] - 1s 15ms/step - loss: 0.3013 - accuracy:
0.8560 - val_loss: 0.7858 - val_accuracy: 0.6840
Epoch 14/30
63/63 [============ ] - 1s 15ms/step - loss: 0.2362 - accuracy:
0.9035 - val loss: 0.8476 - val accuracy: 0.7090
Epoch 15/30
0.9210 - val_loss: 0.9778 - val_accuracy: 0.7110
Epoch 16/30
63/63 [============] - 1s 15ms/step - loss: 0.1793 - accuracy:
0.9300 - val_loss: 0.9949 - val_accuracy: 0.7050
Epoch 17/30
63/63 [============ ] - 1s 15ms/step - loss: 0.1404 - accuracy:
0.9425 - val loss: 1.0254 - val accuracy: 0.7130
Epoch 18/30
0.9550 - val_loss: 1.1929 - val_accuracy: 0.7090
Epoch 19/30
63/63 [============] - 1s 15ms/step - loss: 0.1025 - accuracy:
0.9670 - val_loss: 1.2320 - val_accuracy: 0.6980
Epoch 20/30
63/63 [===========] - 1s 15ms/step - loss: 0.0712 - accuracy:
0.9765 - val_loss: 1.2451 - val_accuracy: 0.7170
Epoch 21/30
0.9765 - val_loss: 1.3301 - val_accuracy: 0.7190
Epoch 22/30
```

```
63/63 [============= ] - 1s 15ms/step - loss: 0.0740 - accuracy:
0.9750 - val_loss: 1.4292 - val_accuracy: 0.7240
Epoch 23/30
63/63 [============] - 1s 15ms/step - loss: 0.0991 - accuracy:
0.9610 - val_loss: 1.1535 - val_accuracy: 0.6940
Epoch 24/30
63/63 [============] - 1s 15ms/step - loss: 0.0606 - accuracy:
0.9790 - val_loss: 1.3067 - val_accuracy: 0.7180
Epoch 25/30
63/63 [============] - 1s 16ms/step - loss: 0.0529 - accuracy:
0.9835 - val_loss: 1.5358 - val_accuracy: 0.7000
Epoch 26/30
63/63 [============] - 1s 16ms/step - loss: 0.0549 - accuracy:
0.9805 - val_loss: 1.4841 - val_accuracy: 0.7070
Epoch 27/30
0.9735 - val_loss: 1.3312 - val_accuracy: 0.7060
Epoch 28/30
63/63 [============] - 1s 15ms/step - loss: 0.0545 - accuracy:
0.9790 - val_loss: 1.3573 - val_accuracy: 0.7170
Epoch 29/30
63/63 [============] - 1s 15ms/step - loss: 0.0374 - accuracy:
0.9890 - val_loss: 1.4857 - val_accuracy: 0.7130
Epoch 30/30
0.9910 - val_loss: 1.4736 - val_accuracy: 0.6950
```

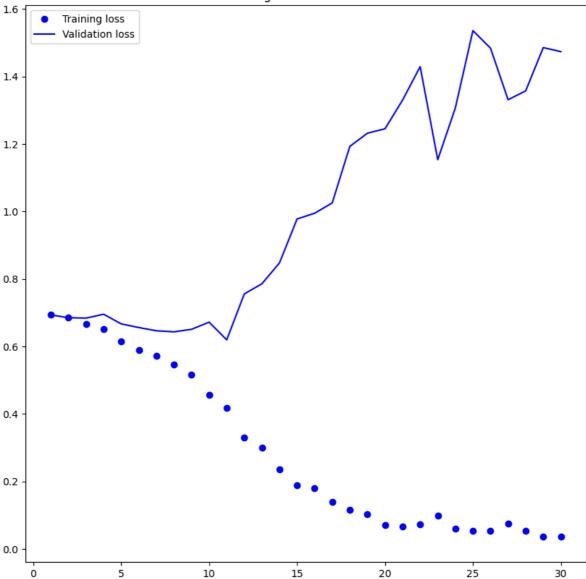
Display the curves of loss and accuracy during training

```
import matplotlib.pyplot as plt
In [20]:
         plt.figure(figsize=(10, 10))
         accuracy = history.history["accuracy"]
         val_accuracy = history.history["val_accuracy"]
         loss = history.history["loss"]
         val_loss = history.history["val_loss"]
         epochs = range(1, len(accuracy) + 1)
         plt.plot(epochs, accuracy, "bo", label="Training accuracy")
         plt.plot(epochs, val_accuracy, "b", label="Validation accuracy")
         plt.title("Training and validation accuracy")
         plt.legend()
         plt.figure()
         plt.figure(figsize=(10, 10))
         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()
         plt.show()
```

Training and validation accuracy



Training and validation loss



Q2. Increase your training sample size. You may pick any amount. Keep the validation and test samples the same as above. Optimize your network (again training from scratch). What performance did you achieve?

```
In [22]: import os, shutil, pathlib

shutil.rmtree("./cats_vs_dogs_small_Q2", ignore_errors=True)

original_dir = pathlib.Path("train")
new_base_dir = pathlib.Path("cats_vs_dogs_small_Q2")

def make_subset(subset_name, start_index, end_index):
    for category in ("cat", "dog"):
        dir = new_base_dir / subset_name / category
        os.makedirs(dir)
        fnames = [f"{category}.{i}.jpg" for i in range(start_index, end_index)]
        for fname in fnames:
```

Display some randomly augmented training images

```
In [24]: plt.figure(figsize=(10, 10))
for images, _ in training_datasets.take(1):
    for i in range(9):
        augmented_images = data_augmentation(images)
        ax = plt.subplot(3, 3, i + 1)
        plt.imshow(augmented_images[0].numpy().astype("uint8"))
        plt.axis("off")
```



















Defining a new convnet that includes image augmentation and dropout

```
In [25]: inputs = keras.Input(shape=(180, 180, 3))
         x = data augmentation(inputs)
         x = layers.Rescaling(1./255)(x)
         x = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool size=2)(x)
         x = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool size=2)(x)
         x = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(x)
         x = layers.Flatten()(x)
         x = layers.Dropout(0.5)(x)
         outputs = layers.Dense(1, activation="sigmoid")(x)
         model = keras.Model(inputs=inputs, outputs=outputs)
         model.compile(loss="binary_crossentropy",
                       optimizer="adam",
                       metrics=["accuracy"])
In [26]:
         callbacks = [
             keras.callbacks.ModelCheckpoint(
                 filepath="convnet_from_scratch_with_augmentation.keras",
                 save_best_only=True,
                 monitor="val_loss")
         history = model.fit(
             training_datasets,
             epochs=50,
             validation_data=valid_datasets,
             callbacks=callbacks)
```

```
Epoch 1/50
63/63 [============] - 4s 21ms/step - loss: 0.6947 - accuracy:
0.5030 - val_loss: 0.6909 - val_accuracy: 0.5880
Epoch 2/50
63/63 [============] - 1s 18ms/step - loss: 0.6858 - accuracy:
0.5535 - val loss: 0.6674 - val accuracy: 0.6060
63/63 [============] - 1s 18ms/step - loss: 0.6721 - accuracy:
0.5915 - val_loss: 0.6612 - val_accuracy: 0.6230
Epoch 4/50
63/63 [============] - 1s 17ms/step - loss: 0.6447 - accuracy:
0.6330 - val_loss: 0.6907 - val_accuracy: 0.5980
Epoch 5/50
63/63 [============] - 1s 18ms/step - loss: 0.6409 - accuracy:
0.6445 - val loss: 0.6404 - val accuracy: 0.6550
Epoch 6/50
63/63 [===========] - 1s 18ms/step - loss: 0.6339 - accuracy:
0.6305 - val_loss: 0.6402 - val_accuracy: 0.6400
Epoch 7/50
63/63 [============] - 1s 16ms/step - loss: 0.6297 - accuracy:
0.6505 - val_loss: 0.6443 - val_accuracy: 0.6430
Epoch 8/50
63/63 [============ - 1s 17ms/step - loss: 0.6206 - accuracy:
0.6680 - val_loss: 0.6827 - val_accuracy: 0.6340
Epoch 9/50
63/63 [============] - 1s 16ms/step - loss: 0.6107 - accuracy:
0.6600 - val loss: 0.7478 - val accuracy: 0.5690
Epoch 10/50
63/63 [============] - 1s 16ms/step - loss: 0.6164 - accuracy:
0.6620 - val_loss: 0.6500 - val_accuracy: 0.6560
Epoch 11/50
63/63 [============ - 1s 17ms/step - loss: 0.6075 - accuracy:
0.6700 - val loss: 0.6637 - val accuracy: 0.6710
Epoch 12/50
63/63 [============] - 1s 19ms/step - loss: 0.6064 - accuracy:
0.6685 - val_loss: 0.6291 - val_accuracy: 0.6530
Epoch 13/50
63/63 [=============] - 1s 19ms/step - loss: 0.6019 - accuracy:
0.6825 - val loss: 0.6059 - val accuracy: 0.6840
Epoch 14/50
0.7025 - val loss: 0.6363 - val accuracy: 0.6620
Epoch 15/50
0.7070 - val_loss: 0.5774 - val_accuracy: 0.7350
Epoch 16/50
63/63 [============] - 1s 18ms/step - loss: 0.5565 - accuracy:
0.7255 - val_loss: 0.5690 - val_accuracy: 0.7210
Epoch 17/50
63/63 [============ ] - 1s 18ms/step - loss: 0.5486 - accuracy:
0.7285 - val loss: 0.5657 - val accuracy: 0.7350
Epoch 18/50
63/63 [============ ] - 1s 18ms/step - loss: 0.5354 - accuracy:
0.7405 - val_loss: 0.5553 - val_accuracy: 0.7460
Epoch 19/50
63/63 [===========] - 1s 16ms/step - loss: 0.4993 - accuracy:
0.7515 - val_loss: 0.5677 - val_accuracy: 0.7090
Epoch 20/50
63/63 [=========== ] - 1s 16ms/step - loss: 0.5100 - accuracy:
0.7345 - val_loss: 0.5991 - val_accuracy: 0.6940
Epoch 21/50
0.7420 - val_loss: 0.5482 - val_accuracy: 0.7350
Epoch 22/50
```

```
0.7610 - val_loss: 0.4924 - val_accuracy: 0.7690
Epoch 23/50
63/63 [============] - 1s 16ms/step - loss: 0.4985 - accuracy:
0.7610 - val_loss: 0.6258 - val_accuracy: 0.7170
Epoch 24/50
63/63 [============] - 1s 17ms/step - loss: 0.4810 - accuracy:
0.7680 - val_loss: 0.5127 - val_accuracy: 0.7720
Epoch 25/50
63/63 [============] - 1s 17ms/step - loss: 0.4627 - accuracy:
0.7785 - val_loss: 0.4974 - val_accuracy: 0.7750
Epoch 26/50
63/63 [============] - 1s 17ms/step - loss: 0.4408 - accuracy:
0.7970 - val_loss: 0.5052 - val_accuracy: 0.7740
Epoch 27/50
0.8030 - val_loss: 0.4932 - val_accuracy: 0.7660
Epoch 28/50
63/63 [============] - 1s 17ms/step - loss: 0.4293 - accuracy:
0.7995 - val_loss: 0.5202 - val_accuracy: 0.7570
Epoch 29/50
63/63 [============] - 1s 19ms/step - loss: 0.4147 - accuracy:
0.8065 - val_loss: 0.4802 - val_accuracy: 0.7920
Epoch 30/50
63/63 [============] - 1s 18ms/step - loss: 0.4196 - accuracy:
0.8135 - val_loss: 0.4653 - val_accuracy: 0.8040
Epoch 31/50
63/63 [============] - 1s 16ms/step - loss: 0.3984 - accuracy:
0.8180 - val_loss: 0.4983 - val_accuracy: 0.7790
Epoch 32/50
63/63 [============] - 1s 18ms/step - loss: 0.4029 - accuracy:
0.8340 - val loss: 0.4506 - val accuracy: 0.7970
Epoch 33/50
63/63 [============] - 1s 17ms/step - loss: 0.3909 - accuracy:
0.8270 - val_loss: 0.4730 - val_accuracy: 0.7950
Epoch 34/50
63/63 [============] - 1s 17ms/step - loss: 0.3766 - accuracy:
0.8340 - val_loss: 0.4678 - val_accuracy: 0.8050
Epoch 35/50
63/63 [===========] - 1s 18ms/step - loss: 0.3781 - accuracy:
0.8350 - val loss: 0.4236 - val accuracy: 0.8080
Epoch 36/50
63/63 [===========] - 1s 17ms/step - loss: 0.3704 - accuracy:
0.8245 - val loss: 0.4933 - val accuracy: 0.7970
Epoch 37/50
63/63 [=============] - 1s 17ms/step - loss: 0.3605 - accuracy:
0.8470 - val_loss: 0.4488 - val_accuracy: 0.7970
Epoch 38/50
63/63 [===========] - 1s 17ms/step - loss: 0.3709 - accuracy:
0.8370 - val loss: 0.4565 - val accuracy: 0.8130
Epoch 39/50
63/63 [============ ] - 1s 18ms/step - loss: 0.3566 - accuracy:
0.8390 - val_loss: 0.4371 - val_accuracy: 0.8220
Epoch 40/50
63/63 [=============] - 1s 18ms/step - loss: 0.3475 - accuracy:
0.8385 - val_loss: 0.4251 - val_accuracy: 0.8070
Epoch 41/50
63/63 [===========] - 1s 19ms/step - loss: 0.3499 - accuracy:
0.8475 - val loss: 0.4166 - val accuracy: 0.8120
Epoch 42/50
63/63 [============ ] - 1s 18ms/step - loss: 0.3482 - accuracy:
0.8510 - val loss: 0.4213 - val accuracy: 0.8050
Epoch 43/50
63/63 [============= ] - 1s 17ms/step - loss: 0.3239 - accuracy:
```

```
0.8570 - val loss: 0.4614 - val accuracy: 0.8040
Epoch 44/50
63/63 [============= ] - 1s 17ms/step - loss: 0.3201 - accuracy:
0.8580 - val_loss: 0.4428 - val_accuracy: 0.8200
Epoch 45/50
63/63 [============ - 1s 17ms/step - loss: 0.2932 - accuracy:
0.8750 - val_loss: 0.4516 - val_accuracy: 0.8160
Epoch 46/50
63/63 [============] - 1s 17ms/step - loss: 0.2732 - accuracy:
0.8815 - val_loss: 0.4551 - val_accuracy: 0.8140
Epoch 47/50
63/63 [============] - 1s 16ms/step - loss: 0.2742 - accuracy:
0.8815 - val_loss: 0.4580 - val_accuracy: 0.8210
Epoch 48/50
0.8770 - val_loss: 0.4472 - val_accuracy: 0.8020
Epoch 49/50
63/63 [============= ] - 1s 17ms/step - loss: 0.2629 - accuracy:
0.8945 - val_loss: 0.4503 - val_accuracy: 0.8200
Epoch 50/50
63/63 [============] - 1s 17ms/step - loss: 0.2576 - accuracy:
0.8865 - val_loss: 0.4284 - val_accuracy: 0.8140
```

Evaluating the model on the test set

Q3. Now change your training sample so that you achieve better performance than those from Steps 1 and 2. This sample size may be larger, or smaller than those in the previous steps. The objective is to find the ideal training sample size to get best prediction results.

Increasing the training sample to 2000, keeping the Validation and test sets the same as before(500 samples)

Defining a new convnet with increased training samples, image augmentation and dropout

```
In [29]:
         inputs = keras.Input(shape=(180, 180, 3))
         x = data_augmentation(inputs)
         x = layers.Rescaling(1./255)(x)
         x = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(x)
         x = layers.MaxPooling2D(pool_size=2)(x)
         x = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(x)
         x = layers.Flatten()(x)
         x = layers.Dropout(0.5)(x)
         outputs = layers.Dense(1, activation="sigmoid")(x)
         model = keras.Model(inputs=inputs, outputs=outputs)
         model.compile(loss="binary_crossentropy",
                       optimizer="adam",
                       metrics=["accuracy"])
In [30]: callbacks = [
             keras.callbacks.ModelCheckpoint(
                 filepath="convnet_from_scratch_with_augmentation1.keras",
                 save_best_only=True,
                 monitor="val_loss")
         history = model.fit(
             training_datasets,
             epochs=50,
             validation data=valid datasets,
             callbacks=callbacks)
```

```
Epoch 1/50
63/63 [============] - 4s 21ms/step - loss: 0.6961 - accuracy:
0.5055 - val_loss: 0.6929 - val_accuracy: 0.5000
Epoch 2/50
63/63 [============] - 1s 18ms/step - loss: 0.6928 - accuracy:
0.5195 - val loss: 0.6894 - val accuracy: 0.5080
63/63 [============] - 1s 18ms/step - loss: 0.6911 - accuracy:
0.5140 - val_loss: 0.6865 - val_accuracy: 0.5380
Epoch 4/50
63/63 [============] - 1s 18ms/step - loss: 0.6882 - accuracy:
0.5445 - val_loss: 0.6822 - val_accuracy: 0.5560
Epoch 5/50
63/63 [============] - 1s 18ms/step - loss: 0.6858 - accuracy:
0.5370 - val loss: 0.6789 - val accuracy: 0.5790
Epoch 6/50
63/63 [============] - 1s 17ms/step - loss: 0.6898 - accuracy:
0.5285 - val_loss: 0.6789 - val_accuracy: 0.6250
Epoch 7/50
63/63 [============] - 1s 19ms/step - loss: 0.6742 - accuracy:
0.5705 - val_loss: 0.6636 - val_accuracy: 0.6120
Epoch 8/50
63/63 [============ - 1s 19ms/step - loss: 0.6746 - accuracy:
0.6010 - val loss: 0.6626 - val accuracy: 0.6060
Epoch 9/50
63/63 [============] - 1s 18ms/step - loss: 0.6596 - accuracy:
0.6120 - val loss: 0.6409 - val accuracy: 0.6580
Epoch 10/50
63/63 [============] - 1s 18ms/step - loss: 0.6455 - accuracy:
0.6290 - val_loss: 0.6367 - val_accuracy: 0.6360
Epoch 11/50
63/63 [============ - 1s 16ms/step - loss: 0.6622 - accuracy:
0.6210 - val loss: 0.6425 - val accuracy: 0.6230
Epoch 12/50
63/63 [============] - 1s 18ms/step - loss: 0.6429 - accuracy:
0.6250 - val_loss: 0.6299 - val_accuracy: 0.6260
Epoch 13/50
63/63 [=============] - 1s 18ms/step - loss: 0.6211 - accuracy:
0.6660 - val_loss: 0.6172 - val_accuracy: 0.6700
Epoch 14/50
0.6775 - val loss: 0.6366 - val accuracy: 0.6460
Epoch 15/50
0.6735 - val_loss: 0.6063 - val_accuracy: 0.6730
Epoch 16/50
63/63 [===========] - 1s 18ms/step - loss: 0.5912 - accuracy:
0.6950 - val_loss: 0.5750 - val_accuracy: 0.6890
Epoch 17/50
63/63 [===========] - 1s 17ms/step - loss: 0.5734 - accuracy:
0.7075 - val loss: 0.6235 - val accuracy: 0.6870
Epoch 18/50
0.6950 - val_loss: 0.6165 - val_accuracy: 0.6790
Epoch 19/50
63/63 [============] - 1s 17ms/step - loss: 0.5654 - accuracy:
0.7035 - val_loss: 0.5886 - val_accuracy: 0.6960
Epoch 20/50
63/63 [===========] - 1s 18ms/step - loss: 0.5339 - accuracy:
0.7285 - val_loss: 0.5409 - val_accuracy: 0.7400
Epoch 21/50
0.7410 - val_loss: 0.5280 - val_accuracy: 0.7460
Epoch 22/50
```

```
63/63 [============] - 1s 17ms/step - loss: 0.5290 - accuracy:
0.7495 - val_loss: 0.5308 - val_accuracy: 0.7400
Epoch 23/50
63/63 [============] - 1s 18ms/step - loss: 0.5219 - accuracy:
0.7425 - val_loss: 0.5280 - val_accuracy: 0.7440
Epoch 24/50
63/63 [============] - 1s 18ms/step - loss: 0.4986 - accuracy:
0.7635 - val_loss: 0.5277 - val_accuracy: 0.7400
Epoch 25/50
63/63 [============] - 1s 16ms/step - loss: 0.4911 - accuracy:
0.7645 - val_loss: 0.6224 - val_accuracy: 0.7030
Epoch 26/50
63/63 [============] - 1s 18ms/step - loss: 0.4569 - accuracy:
0.7875 - val_loss: 0.4905 - val_accuracy: 0.7630
Epoch 27/50
63/63 [============] - 1s 18ms/step - loss: 0.4701 - accuracy:
0.7695 - val_loss: 0.4711 - val_accuracy: 0.7650
Epoch 28/50
63/63 [============] - 1s 16ms/step - loss: 0.4593 - accuracy:
0.7835 - val_loss: 0.5053 - val_accuracy: 0.7700
Epoch 29/50
63/63 [============] - 1s 16ms/step - loss: 0.4392 - accuracy:
0.7965 - val_loss: 0.4947 - val_accuracy: 0.7770
Epoch 30/50
63/63 [============] - 1s 16ms/step - loss: 0.4366 - accuracy:
0.7990 - val_loss: 0.6650 - val_accuracy: 0.6880
Epoch 31/50
63/63 [============] - 1s 16ms/step - loss: 0.4474 - accuracy:
0.7830 - val_loss: 0.4967 - val_accuracy: 0.7720
Epoch 32/50
63/63 [============] - 1s 17ms/step - loss: 0.4335 - accuracy:
0.7980 - val loss: 0.4768 - val accuracy: 0.7810
Epoch 33/50
63/63 [============] - 1s 17ms/step - loss: 0.4085 - accuracy:
0.8095 - val_loss: 0.4935 - val_accuracy: 0.7710
Epoch 34/50
63/63 [============] - 1s 18ms/step - loss: 0.4038 - accuracy:
0.8135 - val_loss: 0.4568 - val_accuracy: 0.7950
Epoch 35/50
63/63 [===========] - 1s 17ms/step - loss: 0.3876 - accuracy:
0.8305 - val loss: 0.4861 - val accuracy: 0.7730
Epoch 36/50
63/63 [===========] - 1s 17ms/step - loss: 0.3743 - accuracy:
0.8335 - val loss: 0.4889 - val accuracy: 0.8000
Epoch 37/50
63/63 [=============] - 1s 16ms/step - loss: 0.3749 - accuracy:
0.8350 - val_loss: 0.4657 - val_accuracy: 0.7960
Epoch 38/50
63/63 [===========] - 1s 16ms/step - loss: 0.3628 - accuracy:
0.8360 - val loss: 0.4763 - val accuracy: 0.7790
Epoch 39/50
63/63 [============ ] - 1s 18ms/step - loss: 0.3785 - accuracy:
0.8265 - val loss: 0.4531 - val accuracy: 0.7920
Epoch 40/50
63/63 [=============] - 1s 17ms/step - loss: 0.3397 - accuracy:
0.8500 - val_loss: 0.4405 - val_accuracy: 0.8010
Epoch 41/50
63/63 [===========] - 1s 16ms/step - loss: 0.3466 - accuracy:
0.8415 - val loss: 0.5223 - val accuracy: 0.7900
Epoch 42/50
63/63 [===========] - 1s 16ms/step - loss: 0.3417 - accuracy:
0.8520 - val loss: 0.4799 - val accuracy: 0.7960
Epoch 43/50
63/63 [============= ] - 1s 16ms/step - loss: 0.3225 - accuracy:
```

```
0.8610 - val loss: 0.4670 - val accuracy: 0.7880
        Epoch 44/50
        63/63 [============= ] - 1s 16ms/step - loss: 0.3506 - accuracy:
        0.8445 - val_loss: 0.4686 - val_accuracy: 0.8030
        Epoch 45/50
        63/63 [============ - 1s 16ms/step - loss: 0.3199 - accuracy:
        0.8585 - val_loss: 0.4413 - val_accuracy: 0.8080
        Epoch 46/50
        63/63 [============] - 1s 16ms/step - loss: 0.3154 - accuracy:
        0.8615 - val_loss: 0.4788 - val_accuracy: 0.7910
        Epoch 47/50
        63/63 [===========] - 1s 17ms/step - loss: 0.3073 - accuracy:
        0.8680 - val_loss: 0.4559 - val_accuracy: 0.8130
        Epoch 48/50
        0.8605 - val_loss: 0.4623 - val_accuracy: 0.7910
        Epoch 49/50
        63/63 [============] - 1s 17ms/step - loss: 0.3168 - accuracy:
        0.8655 - val_loss: 0.4819 - val_accuracy: 0.8080
        Epoch 50/50
        63/63 [============] - 1s 17ms/step - loss: 0.2902 - accuracy:
        0.8715 - val_loss: 0.4863 - val_accuracy: 0.8180
In [31]:
       test model = keras.models.load model(
           "convnet from scratch with augmentation1.keras")
        test_loss, test_acc = test_model.evaluate(testing_datasets)
        print(f"Test accuracy: {test_acc:.3f}")
        32/32 [============ ] - 1s 7ms/step - loss: 0.4733 - accuracy: 0.
        8010
```

A simple convolutional neural network (convnet) was trained with 1,000 examples in the first phase, and it achieved a classification accuracy of about 70%. Overfitting was found to be the main cause for concern. To improve the model, optimisation techniques including data augmentation, early stopping, regularisation, and dropout were then used. By implementing data augmentation, the model's accuracy reached 80%, indicating a notable boost in performance. In order to improve classification accuracy even more after this improvement, efforts were focused on locating the best training samples. In order to combat overfitting, several strategies were investigated, including modifying the training set and using extra optimisation tools. They included adding weight regularisation, integrating dropout, decreasing the network's capacity, and expanding the training sample size. By reducing overfitting and enhancing the model's capacity for generalisation, these techniques were found to be successful.

Q4. Repeat Steps 1-3, but now using a pretrained network. The sample sizes you use in Steps 2 and 3 for the pretrained network may be the same or different from those using the network where you trained from scratch. Again, use any and all optimization techniques to get best performance.

Feature extraction with a pretrained model

Instantiating the VGG16 convolutional base

```
In [32]: convolution_base = keras.applications.vgg16.VGG16(
    weights="imagenet",
    include_top=False,
    input_shape=(180, 180, 3))
```

Test accuracy: 0.801

In []: convolution_base.summary()

Model: "vgg16"

Layer (type)	Output Shape	Param #			
	[(None, 180, 180, 3)]	0			
block1_conv1 (Conv2D)	(None, 180, 180, 64)	1792			
block1_conv2 (Conv2D)	(None, 180, 180, 64)	36928			
<pre>block1_pool (MaxPooling2D)</pre>	(None, 90, 90, 64)	0			
block2_conv1 (Conv2D)	(None, 90, 90, 128)	73856			
block2_conv2 (Conv2D)	(None, 90, 90, 128)	147584			
block2_pool (MaxPooling2D)	(None, 45, 45, 128)	0			
block3_conv1 (Conv2D)	(None, 45, 45, 256)	295168			
block3_conv2 (Conv2D)	(None, 45, 45, 256)	590080			
block3_conv3 (Conv2D)	(None, 45, 45, 256)	590080			
block3_pool (MaxPooling2D)	(None, 22, 22, 256)	0			
block4_conv1 (Conv2D)	(None, 22, 22, 512)	1180160			
block4_conv2 (Conv2D)	(None, 22, 22, 512)	2359808			
block4_conv3 (Conv2D)	(None, 22, 22, 512)	2359808			
block4_pool (MaxPooling2D)	(None, 11, 11, 512)	0			
block5_conv1 (Conv2D)	(None, 11, 11, 512)	2359808			
block5_conv2 (Conv2D)	(None, 11, 11, 512)	2359808			
block5_conv3 (Conv2D)	(None, 11, 11, 512)	2359808			
block5_pool (MaxPooling2D)	(None, 5, 5, 512)	0			
Total params: 14714688 (56.13 MB) Trainable params: 14714688 (56.13 MB) Non-trainable params: 0 (0.00 Byte)					

Feature extraction without data augmentation using a pretrained model

Extracting the VGG16 features and corresponding labels

```
In [33]: import numpy as np

def get_features_and_labels(dataset):
    all_features = []
    all_labels = []
```

```
for images, labels in dataset:
    preprocessed_images = keras.applications.vgg16.preprocess_input(images)
    features = convolution_base.predict(preprocessed_images)
    all_features.append(features)
    all_labels.append(labels)
    return np.concatenate(all_features), np.concatenate(all_labels)

train_features, train_labels = get_features_and_labels(training_datasets)
val_features, val_labels = get_features_and_labels(valid_datasets)
test_features, test_labels = get_features_and_labels(testing_datasets)
```

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```
In [34]: train_features.shape
Out[34]: (2000, 5, 5, 512)
```

Defining and training the densely connected classifier

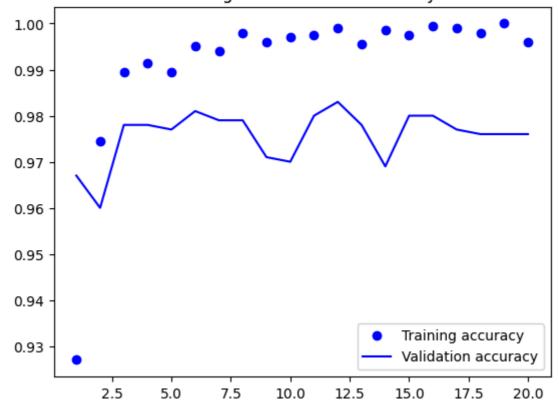
```
In [35]: inputs = keras.Input(shape=(5, 5, 512))
         x = layers.Flatten()(inputs)
         x = layers.Dense(256)(x)
         x = layers.Dropout(0.5)(x)
         outputs = layers.Dense(1, activation="sigmoid")(x)
         model = keras.Model(inputs, outputs)
         model.compile(loss="binary_crossentropy",
                       optimizer="rmsprop",
                        metrics=["accuracy"])
         callbacks = [
             keras.callbacks.ModelCheckpoint(
               filepath="feature_extraction.keras",
               save_best_only=True,
               monitor="val_loss")
         history = model.fit(
             train_features, train_labels,
             epochs=20,
             validation_data=(val_features, val_labels),
             callbacks=callbacks)
```

```
Epoch 1/20
63/63 [============] - 1s 9ms/step - loss: 11.6859 - accuracy:
0.9270 - val_loss: 3.9916 - val_accuracy: 0.9670
Epoch 2/20
63/63 [============] - 0s 4ms/step - loss: 3.6200 - accuracy: 0.
9745 - val loss: 8.7446 - val accuracy: 0.9600
63/63 [===========] - 0s 6ms/step - loss: 1.5690 - accuracy: 0.
9895 - val_loss: 2.7876 - val_accuracy: 0.9780
Epoch 4/20
63/63 [============] - 0s 4ms/step - loss: 1.2622 - accuracy: 0.
9915 - val_loss: 4.1953 - val_accuracy: 0.9780
Epoch 5/20
63/63 [===========] - 0s 4ms/step - loss: 0.7950 - accuracy: 0.
9895 - val loss: 4.0060 - val accuracy: 0.9770
Epoch 6/20
63/63 [===========] - 0s 4ms/step - loss: 0.5633 - accuracy: 0.
9950 - val_loss: 4.1504 - val_accuracy: 0.9810
Epoch 7/20
63/63 [============] - 0s 4ms/step - loss: 0.7477 - accuracy: 0.
9940 - val_loss: 4.4786 - val_accuracy: 0.9790
Epoch 8/20
63/63 [============ ] - 0s 4ms/step - loss: 0.2188 - accuracy: 0.
9980 - val_loss: 4.6182 - val_accuracy: 0.9790
Epoch 9/20
63/63 [===========] - 0s 5ms/step - loss: 0.3759 - accuracy: 0.
9960 - val_loss: 5.8414 - val_accuracy: 0.9710
Epoch 10/20
63/63 [============ ] - 0s 4ms/step - loss: 0.7579 - accuracy: 0.
9970 - val_loss: 6.3881 - val_accuracy: 0.9700
Epoch 11/20
63/63 [============ ] - 0s 4ms/step - loss: 0.4807 - accuracy: 0.
9975 - val loss: 3.7349 - val accuracy: 0.9800
Epoch 12/20
63/63 [============] - 0s 4ms/step - loss: 0.0891 - accuracy: 0.
9990 - val_loss: 3.8855 - val_accuracy: 0.9830
Epoch 13/20
63/63 [============= ] - 0s 5ms/step - loss: 0.3931 - accuracy: 0.
9955 - val_loss: 4.6805 - val_accuracy: 0.9780
Epoch 14/20
63/63 [============ ] - 0s 4ms/step - loss: 0.1893 - accuracy: 0.
9985 - val loss: 7.4637 - val accuracy: 0.9690
Epoch 15/20
63/63 [===========] - 0s 4ms/step - loss: 0.3693 - accuracy: 0.
9975 - val_loss: 4.2531 - val_accuracy: 0.9800
Epoch 16/20
63/63 [=========== ] - 0s 4ms/step - loss: 0.0770 - accuracy: 0.
9995 - val_loss: 4.6612 - val_accuracy: 0.9800
Epoch 17/20
63/63 [============ ] - 0s 4ms/step - loss: 0.0194 - accuracy: 0.
9990 - val loss: 5.0824 - val accuracy: 0.9770
Epoch 18/20
63/63 [============ ] - 0s 4ms/step - loss: 0.2133 - accuracy: 0.
9980 - val_loss: 5.7802 - val_accuracy: 0.9760
Epoch 19/20
y: 1.0000 - val_loss: 5.7796 - val_accuracy: 0.9760
Epoch 20/20
63/63 [============ ] - 0s 5ms/step - loss: 0.2448 - accuracy: 0.
9960 - val_loss: 5.4655 - val_accuracy: 0.9760
```

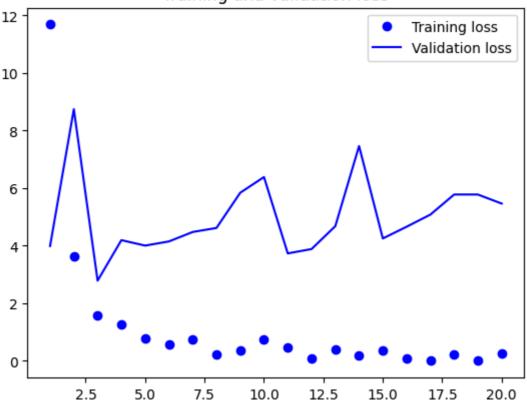
Plot the results

```
import matplotlib.pyplot as plt
In [36]:
          acc = history.history["accuracy"]
         val_acc = history.history["val_accuracy"]
         loss = history.history["loss"]
         val_loss = history.history["val_loss"]
         epochs = range(1, len(acc) + 1)
          plt.plot(epochs, acc, "bo", label="Training accuracy")
         plt.plot(epochs, val_acc, "b", label="Validation accuracy")
         plt.title("Training and validation accuracy")
          plt.legend()
         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()
          plt.show()
```

Training and validation accuracy



Training and validation loss



Feature extraction with data augmentation using a pretrained model

Instantiating and freezing the VGG16 convolutional base

```
In [37]: convolution_base = keras.applications.vgg16.VGG16(
    weights="imagenet",
    include_top=False)
convolution_base.trainable = False
```

This is the number of trainable weights before freezing the conv base: 26

This is the number of trainable weights after freezing the conv base: 0

Adding a data augmentation stage and a classifier to the convolutional base

```
In [41]:
    augmentation2 = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
    )
    input22 = keras.Input(shape=(180, 180, 3))
    x1 = augmentation2(input22)
    x1 = keras.layers.Lambda(
    lambda x: keras.applications.vgg16.preprocess_input(x))(x1)
    x1 = convolution_base(x1)
```

```
x1 = layers.Flatten()(x1)
x1 = layers.Dense(256)(x1)
x1 = layers.Dropout(0.5)(x1)
outputs = layers.Dense(1, activation="sigmoid")(x1)
model = keras.Model(input22, outputs)
model.compile(loss="binary_crossentropy",
optimizer="rmsprop",
metrics=["accuracy"])
```

```
Epoch 1/50
63/63 [============] - 4s 38ms/step - loss: 27.3247 - accuracy:
0.8835 - val_loss: 12.5715 - val_accuracy: 0.9330
Epoch 2/50
63/63 [============] - 2s 28ms/step - loss: 7.2298 - accuracy:
0.9505 - val loss: 19.3305 - val accuracy: 0.9120
0.9550 - val_loss: 4.5673 - val_accuracy: 0.9730
Epoch 4/50
63/63 [============] - 2s 34ms/step - loss: 4.8890 - accuracy:
0.9630 - val_loss: 4.5106 - val_accuracy: 0.9740
Epoch 5/50
63/63 [============ ] - 2s 35ms/step - loss: 3.7784 - accuracy:
0.9655 - val loss: 2.2957 - val accuracy: 0.9820
Epoch 6/50
63/63 [============ ] - 2s 28ms/step - loss: 4.3997 - accuracy:
0.9655 - val_loss: 2.8734 - val_accuracy: 0.9820
Epoch 7/50
63/63 [============] - 2s 27ms/step - loss: 3.3774 - accuracy:
0.9695 - val_loss: 4.8522 - val_accuracy: 0.9670
Epoch 8/50
0.9650 - val_loss: 3.0557 - val_accuracy: 0.9860
Epoch 9/50
63/63 [============] - 2s 28ms/step - loss: 2.6864 - accuracy:
0.9740 - val loss: 2.8496 - val accuracy: 0.9830
Epoch 10/50
63/63 [============= ] - 2s 28ms/step - loss: 1.7145 - accuracy:
0.9790 - val_loss: 5.7142 - val_accuracy: 0.9700
Epoch 11/50
0.9755 - val loss: 2.4987 - val accuracy: 0.9820
Epoch 12/50
63/63 [============= ] - 2s 28ms/step - loss: 2.1935 - accuracy:
0.9780 - val_loss: 2.5653 - val_accuracy: 0.9820
Epoch 13/50
63/63 [============== ] - 2s 27ms/step - loss: 2.0375 - accuracy:
0.9770 - val loss: 3.9650 - val accuracy: 0.9750
Epoch 14/50
63/63 [============ ] - 2s 27ms/step - loss: 2.1808 - accuracy:
0.9770 - val loss: 3.3794 - val accuracy: 0.9770
Epoch 15/50
0.9825 - val_loss: 2.4793 - val_accuracy: 0.9800
Epoch 16/50
63/63 [============] - 2s 27ms/step - loss: 1.7489 - accuracy:
0.9740 - val_loss: 2.3834 - val_accuracy: 0.9810
Epoch 17/50
63/63 [============ ] - 2s 28ms/step - loss: 1.1833 - accuracy:
0.9785 - val loss: 2.5114 - val accuracy: 0.9810
Epoch 18/50
0.9765 - val_loss: 4.6437 - val_accuracy: 0.9720
Epoch 19/50
63/63 [============] - 2s 34ms/step - loss: 1.7864 - accuracy:
0.9800 - val_loss: 1.6652 - val_accuracy: 0.9820
Epoch 20/50
63/63 [============ ] - 2s 28ms/step - loss: 0.9366 - accuracy:
0.9865 - val_loss: 4.9521 - val_accuracy: 0.9680
Epoch 21/50
0.9805 - val_loss: 2.6013 - val_accuracy: 0.9790
Epoch 22/50
```

```
0.9800 - val_loss: 2.4307 - val_accuracy: 0.9790
Epoch 23/50
63/63 [============] - 2s 28ms/step - loss: 0.6693 - accuracy:
0.9880 - val_loss: 2.9397 - val_accuracy: 0.9760
Epoch 24/50
63/63 [============] - 2s 28ms/step - loss: 0.9943 - accuracy:
0.9825 - val_loss: 2.4133 - val_accuracy: 0.9800
Epoch 25/50
63/63 [============] - 2s 28ms/step - loss: 0.7520 - accuracy:
0.9840 - val_loss: 2.0440 - val_accuracy: 0.9830
Epoch 26/50
63/63 [============] - 2s 28ms/step - loss: 0.9370 - accuracy:
0.9835 - val_loss: 2.4063 - val_accuracy: 0.9780
Epoch 27/50
63/63 [============ ] - 2s 28ms/step - loss: 1.1855 - accuracy:
0.9815 - val_loss: 1.8439 - val_accuracy: 0.9800
Epoch 28/50
63/63 [============] - 2s 35ms/step - loss: 0.7571 - accuracy:
0.9845 - val_loss: 1.5188 - val_accuracy: 0.9810
Epoch 29/50
63/63 [============ ] - 2s 28ms/step - loss: 0.8915 - accuracy:
0.9850 - val_loss: 1.6826 - val_accuracy: 0.9830
Epoch 30/50
63/63 [============] - 2s 34ms/step - loss: 0.7123 - accuracy:
0.9825 - val_loss: 1.2195 - val_accuracy: 0.9830
Epoch 31/50
63/63 [============] - 2s 34ms/step - loss: 0.4742 - accuracy:
0.9920 - val_loss: 1.0346 - val_accuracy: 0.9840
Epoch 32/50
63/63 [============] - 2s 28ms/step - loss: 0.8664 - accuracy:
0.9855 - val loss: 1.2807 - val accuracy: 0.9840
Epoch 33/50
63/63 [============] - 2s 28ms/step - loss: 0.6950 - accuracy:
0.9875 - val_loss: 1.3634 - val_accuracy: 0.9830
Epoch 34/50
63/63 [============= ] - 2s 28ms/step - loss: 1.1008 - accuracy:
0.9790 - val_loss: 1.4107 - val_accuracy: 0.9820
Epoch 35/50
63/63 [============ ] - 2s 28ms/step - loss: 0.8762 - accuracy:
0.9820 - val loss: 1.3989 - val accuracy: 0.9820
Epoch 36/50
63/63 [============ ] - 2s 28ms/step - loss: 0.4522 - accuracy:
0.9890 - val loss: 1.4284 - val accuracy: 0.9810
Epoch 37/50
63/63 [==============] - 2s 28ms/step - loss: 0.4772 - accuracy:
0.9870 - val_loss: 1.3235 - val_accuracy: 0.9800
Epoch 38/50
63/63 [============ ] - 2s 28ms/step - loss: 0.5073 - accuracy:
0.9820 - val loss: 1.3820 - val accuracy: 0.9860
Epoch 39/50
63/63 [============ ] - 2s 27ms/step - loss: 0.4729 - accuracy:
0.9840 - val_loss: 1.4312 - val_accuracy: 0.9830
Epoch 40/50
63/63 [============== ] - 2s 28ms/step - loss: 0.3839 - accuracy:
0.9900 - val_loss: 3.0758 - val_accuracy: 0.9740
Epoch 41/50
63/63 [============ ] - 2s 28ms/step - loss: 0.5142 - accuracy:
0.9865 - val_loss: 1.8887 - val_accuracy: 0.9830
Epoch 42/50
63/63 [============ ] - 2s 28ms/step - loss: 0.6147 - accuracy:
0.9855 - val loss: 2.0303 - val accuracy: 0.9800
Epoch 43/50
63/63 [=============] - 2s 28ms/step - loss: 0.2492 - accuracy:
```

```
0.9930 - val loss: 1.6009 - val accuracy: 0.9820
Epoch 44/50
63/63 [============= ] - 2s 29ms/step - loss: 0.4795 - accuracy:
0.9865 - val_loss: 2.1461 - val_accuracy: 0.9790
Epoch 45/50
63/63 [============ ] - 2s 28ms/step - loss: 0.3600 - accuracy:
0.9940 - val_loss: 1.6653 - val_accuracy: 0.9790
Epoch 46/50
63/63 [============= ] - 2s 28ms/step - loss: 0.4117 - accuracy:
0.9860 - val_loss: 1.6768 - val_accuracy: 0.9780
Epoch 47/50
63/63 [============= ] - 2s 27ms/step - loss: 0.7265 - accuracy:
0.9850 - val_loss: 1.4756 - val_accuracy: 0.9830
Epoch 48/50
0.9870 - val_loss: 2.0025 - val_accuracy: 0.9750
Epoch 49/50
63/63 [============= ] - 2s 28ms/step - loss: 0.6140 - accuracy:
0.9840 - val_loss: 1.5809 - val_accuracy: 0.9780
Epoch 50/50
63/63 [============] - 2s 28ms/step - loss: 0.5698 - accuracy:
0.9870 - val_loss: 1.1620 - val_accuracy: 0.9850
```

Evaluating the model on the test set

A pretrained VGG16 model with Fine-tuning

Fine-tuning entails unfreezing a few top layers of a frozen model foundation used for feature extraction and training both the newly added element of the model (in this case, the fully connected classifier) and these top layers at the same time. This is referred to as fine-tuning because it modifies the more abstract representations of the model that are being reused to make them more relevant to the task at hand.

```
In [44]: convolution_base.summary()
```

Model: "vgg16"

```
Layer (type)
                            Output Shape
                                                     Param #
 input_6 (InputLayer)
                            [(None, None, None, 3)]
 block1_conv1 (Conv2D)
                            (None, None, None, 64)
                                                     1792
                            (None, None, None, 64)
 block1_conv2 (Conv2D)
                                                     36928
 block1_pool (MaxPooling2D) (None, None, 64)
 block2_conv1 (Conv2D)
                            (None, None, None, 128)
                                                     73856
 block2 conv2 (Conv2D)
                            (None, None, None, 128)
                                                     147584
 block2_pool (MaxPooling2D) (None, None, None, 128)
 block3_conv1 (Conv2D)
                            (None, None, None, 256)
                                                     295168
 block3_conv2 (Conv2D)
                            (None, None, None, 256)
                                                     590080
 block3_conv3 (Conv2D)
                            (None, None, None, 256)
                                                     590080
 block3_pool (MaxPooling2D) (None, None, None, 256)
 block4_conv1 (Conv2D)
                            (None, None, None, 512)
                                                     1180160
 block4_conv2 (Conv2D)
                            (None, None, None, 512)
                                                     2359808
 block4_conv3 (Conv2D)
                                                     2359808
                            (None, None, None, 512)
 block4 pool (MaxPooling2D) (None, None, None, 512)
 block5_conv1 (Conv2D)
                            (None, None, None, 512)
                                                     2359808
 block5_conv2 (Conv2D)
                            (None, None, None, 512)
                                                     2359808
 block5_conv3 (Conv2D)
                            (None, None, None, 512)
                                                     2359808
 block5 pool (MaxPooling2D) (None, None, None, 512)
______
Total params: 14714688 (56.13 MB)
Trainable params: 0 (0.00 Byte)
Non-trainable params: 14714688 (56.13 MB)
convolution base.trainable = True
for layer in convolution base.layers[:-4]:
    layer.trainable = False
```

```
In [45]:
```

Fine-tuning the model

```
model.compile(loss="binary_crossentropy",
              optimizer=keras.optimizers.RMSprop(learning_rate=1e-5),
              metrics=["accuracy"])
callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="fine_tuning.keras",
        save_best_only=True,
        monitor="val_loss")
```

```
history = model.fit(
    training_datasets,
    epochs=30,
    validation_data=valid_datasets,
    callbacks=callbacks)
```

```
Epoch 1/30
63/63 [============] - 5s 43ms/step - loss: 0.4846 - accuracy:
0.9885 - val_loss: 1.5362 - val_accuracy: 0.9820
Epoch 2/30
63/63 [=============] - 2s 35ms/step - loss: 0.4957 - accuracy:
0.9885 - val loss: 1.4219 - val accuracy: 0.9810
63/63 [============] - 2s 26ms/step - loss: 0.2054 - accuracy:
0.9935 - val_loss: 1.5086 - val_accuracy: 0.9780
Epoch 4/30
63/63 [============= ] - 2s 35ms/step - loss: 0.3153 - accuracy:
0.9900 - val_loss: 1.3695 - val_accuracy: 0.9840
Epoch 5/30
63/63 [============ ] - 2s 27ms/step - loss: 0.2380 - accuracy:
0.9915 - val loss: 2.0523 - val accuracy: 0.9780
Epoch 6/30
63/63 [============ ] - 2s 27ms/step - loss: 0.2246 - accuracy:
0.9930 - val_loss: 1.3737 - val_accuracy: 0.9840
Epoch 7/30
63/63 [============= ] - 2s 34ms/step - loss: 0.3267 - accuracy:
0.9940 - val_loss: 1.3592 - val_accuracy: 0.9880
Epoch 8/30
0.9935 - val_loss: 1.3623 - val_accuracy: 0.9830
Epoch 9/30
63/63 [============ ] - 2s 35ms/step - loss: 0.2157 - accuracy:
0.9925 - val_loss: 1.3492 - val_accuracy: 0.9850
Epoch 10/30
63/63 [============] - 2s 35ms/step - loss: 0.1085 - accuracy:
0.9960 - val_loss: 1.1294 - val_accuracy: 0.9880
Epoch 11/30
0.9975 - val loss: 1.1505 - val accuracy: 0.9890
Epoch 12/30
63/63 [============= ] - 2s 26ms/step - loss: 0.2375 - accuracy:
0.9940 - val_loss: 1.2978 - val_accuracy: 0.9860
Epoch 13/30
63/63 [==============] - 2s 26ms/step - loss: 0.2402 - accuracy:
0.9940 - val loss: 1.7496 - val accuracy: 0.9800
Epoch 14/30
63/63 [============ ] - 2s 27ms/step - loss: 0.2031 - accuracy:
0.9945 - val loss: 1.3023 - val accuracy: 0.9830
Epoch 15/30
0.9950 - val_loss: 1.4386 - val_accuracy: 0.9830
Epoch 16/30
63/63 [============] - 2s 27ms/step - loss: 0.2874 - accuracy:
0.9935 - val_loss: 1.3548 - val_accuracy: 0.9840
Epoch 17/30
63/63 [============ ] - 2s 27ms/step - loss: 0.0984 - accuracy:
0.9955 - val loss: 1.1793 - val accuracy: 0.9830
Epoch 18/30
0.9950 - val_loss: 1.1172 - val_accuracy: 0.9840
Epoch 19/30
63/63 [============] - 2s 27ms/step - loss: 0.1054 - accuracy:
0.9945 - val_loss: 1.4955 - val_accuracy: 0.9810
Epoch 20/30
63/63 [============ ] - 2s 26ms/step - loss: 0.0273 - accuracy:
0.9975 - val_loss: 1.3001 - val_accuracy: 0.9830
Epoch 21/30
0.9935 - val_loss: 1.5934 - val_accuracy: 0.9810
Epoch 22/30
```

```
63/63 [============= ] - 2s 27ms/step - loss: 0.1193 - accuracy:
        0.9940 - val_loss: 1.1595 - val_accuracy: 0.9870
        Epoch 23/30
        63/63 [============ ] - 2s 27ms/step - loss: 0.2087 - accuracy:
        0.9950 - val_loss: 1.2913 - val_accuracy: 0.9840
        Epoch 24/30
        63/63 [============ ] - 2s 27ms/step - loss: 0.0179 - accuracy:
        0.9985 - val_loss: 1.1781 - val_accuracy: 0.9890
        Epoch 25/30
        63/63 [=============] - 2s 26ms/step - loss: 0.1361 - accuracy:
        0.9965 - val_loss: 1.1303 - val_accuracy: 0.9870
        Epoch 26/30
        63/63 [============] - 2s 26ms/step - loss: 0.0239 - accuracy:
        0.9980 - val_loss: 1.1425 - val_accuracy: 0.9870
        Epoch 27/30
        63/63 [============= ] - 2s 26ms/step - loss: 0.0420 - accuracy:
        0.9975 - val_loss: 1.2429 - val_accuracy: 0.9830
        Epoch 28/30
        63/63 [============] - 2s 26ms/step - loss: 0.0958 - accuracy:
        0.9965 - val_loss: 1.4917 - val_accuracy: 0.9790
        Epoch 29/30
        63/63 [============ ] - 2s 26ms/step - loss: 0.0587 - accuracy:
        0.9965 - val_loss: 1.1475 - val_accuracy: 0.9860
        Epoch 30/30
        63/63 [============ - 2s 26ms/step - loss: 0.1359 - accuracy:
        0.9960 - val_loss: 1.3562 - val_accuracy: 0.9830
In [47]: model = keras.models.load_model("fine_tuning.keras", safe_mode=False)
        test_loss, test_acc = model.evaluate(testing_datasets)
        print(f"Test accuracy: {test_acc:.3f}")
        32/32 [============ ] - 1s 17ms/step - loss: 2.2150 - accuracy:
        0.9730
        Test accuracy: 0.973
```