```
#####################################################
# Advanced Machine Learning                         #
# Assignment 2 - Convolution - Cats Vs Dogs data set#
# Name: Divya Chandrasekaran                        #
# Due Date: 24/03/2024                              #
#####################################################
```

```
!mkdir ~/.kaggle
!cp kaggle.json ~/.kaggle/
!chmod 600 ~/.kaggle/kaggle.json
```

```
!kaggle competitions download -c dogs-vs-cats
```

```
     Downloading dogs-vs-cats.zip to /content
      97% 790M/812M [00:04<00:00, 201MB/s]
     100% 812M/812M [00:04<00:00, 203MB/s]
```

```
!unzip -qq dogs-vs-cats.zip
```

```
!unzip -qq test1.zip
```

```
!unzip -qq train.zip
```

Question 1

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?

Copying images to training, validation, and test directories.

```
import os, shutil, pathlib

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

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:
            shutil.copyfile(src=original_dir / fname,
                            dst=dir / fname)
#Initially taking 1000 samples for training set
make_subset("train", start_index=0, end_index=1000)
#500 samples for validation set
make_subset("validation", start_index=1000, end_index=1500)
#500 for test set
make_subset("test", start_index=1500, end_index=2000)
```

Data preprocessing

Using image_dataset_from_directory to read images

```
from tensorflow.keras.utils import image_dataset_from_directory

train_dataset = image_dataset_from_directory(
    new_base_dir / "train",
    image_size=(180, 180),
    batch_size=32)
validation_dataset = image_dataset_from_directory(
    new_base_dir / "validation",
    image_size=(180, 180),
    batch_size=32)
test_dataset = 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.
```

```
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)
```

```
for i, element in enumerate(dataset):
    print(element.shape)
    if i >= 2:
        break
```

```
(16,)
(16,)
(16,)
```

```
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)
```

```
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
```

```
WARNING:tensorflow:From /usr/local/lib/python3.9/dist-packages/tensorflow/python/autograph/pyct/static_analysis/liveness.py:83: Analyzer
Instructions for updating:
Lambda fuctions will be no more assumed to be used in the statement where they are used, or at least in the same block. https://github.c
(4, 4)
(4, 4)
(4, 4)
```

```
for data_batch, labels_batch in train_dataset:
    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,)
```

Using Convolution Neural Networks

Building the model

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

inputs = keras.Input(shape=(180, 180, 3))
x = layers.Rescaling(1./255)(inputs)
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="rmsprop",
              metrics=["accuracy"])
```

```
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 180, 180, 3)]     0

 rescaling (Rescaling)       (None, 180, 180, 3)       0

 conv2d (Conv2D)             (None, 178, 178, 32)      896

 max_pooling2d (MaxPooling2D  (None, 89, 89, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 87, 87, 64)        18496

 max_pooling2d_1 (MaxPooling  (None, 43, 43, 64)       0
 2D)

 conv2d_2 (Conv2D)           (None, 41, 41, 128)       73856

 max_pooling2d_2 (MaxPooling  (None, 20, 20, 128)      0
 2D)

 conv2d_3 (Conv2D)           (None, 18, 18, 256)       295168

 max_pooling2d_3 (MaxPooling  (None, 9, 9, 256)        0
 2D)

 conv2d_4 (Conv2D)           (None, 7, 7, 256)         590080

 flatten (Flatten)           (None, 12544)             0

 dropout (Dropout)           (None, 12544)             0

 dense (Dense)               (None, 1)                 12545

=================================================================
Total params: 991,041
Trainable params: 991,041
Non-trainable params: 0
_________________________________________________________________
```

From the above model summary, we can observe that the model might overfit, and so it's best to use regularization techniques in data processing stage.

Next, we will have to convert all the images to tensors.

Fitting the model using a Dataset

Callbacks are generally used to save the model's weights after every epoch or to stop training early if the model is not improving.

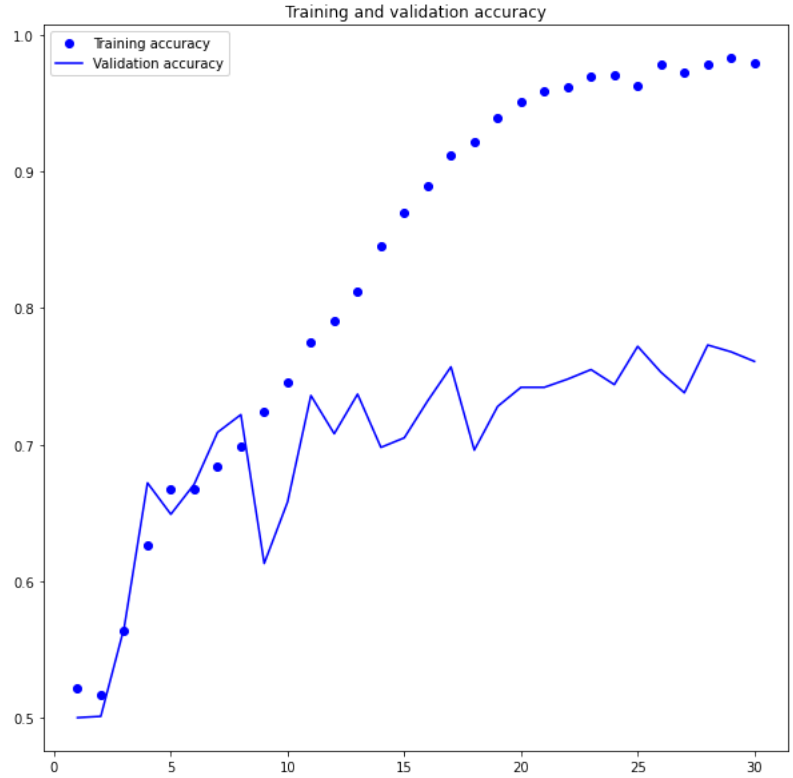
Moreover, these callbacks are mainly used to log metrics, visualize the model's performance, or schedule learning rate changes.

```
callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch.keras",
        save_best_only=True,
        monitor="val_loss")
]
history = model.fit(
    train_dataset,
    epochs=30,
    validation_data=validation_dataset,
    callbacks=callbacks)
```

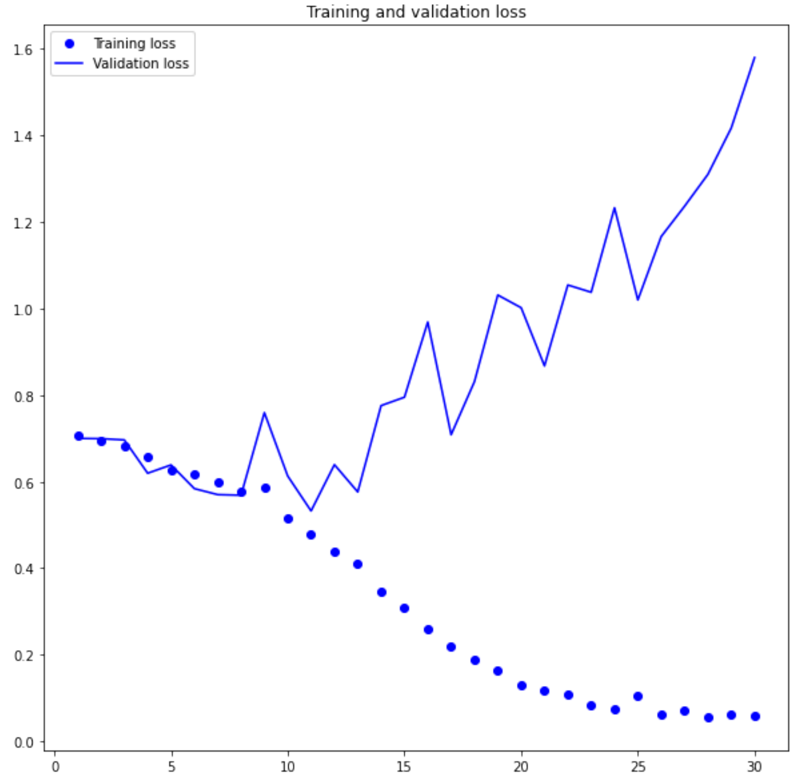
```
Epoch 1/30
63/63 [==============================] - 19s 76ms/step - loss: 0.7079 - accuracy: 0.5215 - val_loss: 0.6996 - val_accuracy: 0.5000
Epoch 2/30
63/63 [==============================] - 5s 82ms/step - loss: 0.6932 - accuracy: 0.5165 - val_loss: 0.6991 - val_accuracy: 0.5010
Epoch 3/30
63/63 [==============================] - 4s 66ms/step - loss: 0.6811 - accuracy: 0.5635 - val_loss: 0.6962 - val_accuracy: 0.5660
Epoch 4/30
63/63 [==============================] - 5s 80ms/step - loss: 0.6561 - accuracy: 0.6260 - val_loss: 0.6193 - val_accuracy: 0.6720
Epoch 5/30
63/63 [==============================] - 4s 63ms/step - loss: 0.6277 - accuracy: 0.6675 - val_loss: 0.6385 - val_accuracy: 0.6490
Epoch 6/30
63/63 [==============================] - 4s 63ms/step - loss: 0.6176 - accuracy: 0.6675 - val_loss: 0.5838 - val_accuracy: 0.6710
Epoch 7/30
63/63 [==============================] - 5s 82ms/step - loss: 0.5976 - accuracy: 0.6845 - val_loss: 0.5699 - val_accuracy: 0.7090
Epoch 8/30
63/63 [==============================] - 4s 63ms/step - loss: 0.5772 - accuracy: 0.6985 - val_loss: 0.5685 - val_accuracy: 0.7220
Epoch 9/30
63/63 [==============================] - 9s 145ms/step - loss: 0.5853 - accuracy: 0.7245 - val_loss: 0.7591 - val_accuracy: 0.6130
Epoch 10/30
63/63 [==============================] - 4s 64ms/step - loss: 0.5147 - accuracy: 0.7455 - val_loss: 0.6128 - val_accuracy: 0.6580
Epoch 11/30
63/63 [==============================] - 5s 80ms/step - loss: 0.4785 - accuracy: 0.7755 - val_loss: 0.5323 - val_accuracy: 0.7360
Epoch 12/30
63/63 [==============================] - 4s 64ms/step - loss: 0.4391 - accuracy: 0.7905 - val_loss: 0.6391 - val_accuracy: 0.7080
Epoch 13/30
63/63 [==============================] - 4s 64ms/step - loss: 0.4096 - accuracy: 0.8125 - val_loss: 0.5761 - val_accuracy: 0.7370
Epoch 14/30
63/63 [==============================] - 5s 82ms/step - loss: 0.3468 - accuracy: 0.8455 - val_loss: 0.7753 - val_accuracy: 0.6980
Epoch 15/30
63/63 [==============================] - 6s 86ms/step - loss: 0.3097 - accuracy: 0.8695 - val_loss: 0.7947 - val_accuracy: 0.7050
Epoch 16/30
63/63 [==============================] - 4s 64ms/step - loss: 0.2605 - accuracy: 0.8890 - val_loss: 0.9682 - val_accuracy: 0.7320
Epoch 17/30
63/63 [==============================] - 7s 98ms/step - loss: 0.2206 - accuracy: 0.9115 - val_loss: 0.7081 - val_accuracy: 0.7570
Epoch 18/30
63/63 [==============================] - 5s 73ms/step - loss: 0.1878 - accuracy: 0.9220 - val_loss: 0.8307 - val_accuracy: 0.6960
Epoch 19/30
63/63 [==============================] - 5s 79ms/step - loss: 0.1647 - accuracy: 0.9390 - val_loss: 1.0305 - val_accuracy: 0.7280
Epoch 20/30
63/63 [==============================] - 4s 63ms/step - loss: 0.1308 - accuracy: 0.9515 - val_loss: 1.0012 - val_accuracy: 0.7420
Epoch 21/30
63/63 [==============================] - 4s 62ms/step - loss: 0.1177 - accuracy: 0.9585 - val_loss: 0.8670 - val_accuracy: 0.7420
Epoch 22/30
63/63 [==============================] - 5s 82ms/step - loss: 0.1104 - accuracy: 0.9620 - val_loss: 1.0537 - val_accuracy: 0.7480
Epoch 23/30
63/63 [==============================] - 5s 80ms/step - loss: 0.0848 - accuracy: 0.9695 - val_loss: 1.0369 - val_accuracy: 0.7550
Epoch 24/30
63/63 [==============================] - 4s 63ms/step - loss: 0.0749 - accuracy: 0.9710 - val_loss: 1.2318 - val_accuracy: 0.7440
Epoch 25/30
63/63 [==============================] - 5s 70ms/step - loss: 0.1052 - accuracy: 0.9630 - val_loss: 1.0192 - val_accuracy: 0.7720
Epoch 26/30
63/63 [==============================] - 5s 79ms/step - loss: 0.0628 - accuracy: 0.9790 - val_loss: 1.1654 - val_accuracy: 0.7530
Epoch 27/30
63/63 [==============================] - 4s 63ms/step - loss: 0.0716 - accuracy: 0.9725 - val_loss: 1.2354 - val_accuracy: 0.7380
Epoch 28/30
63/63 [==============================] - 6s 85ms/step - loss: 0.0563 - accuracy: 0.9790 - val_loss: 1.3089 - val_accuracy: 0.7730
Epoch 29/30
63/63 [==============================] - 5s 82ms/step - loss: 0.0621 - accuracy: 0.9835 - val_loss: 1.4159 - val_accuracy: 0.7680
```

Displaying curves of loss and accuracy during training

```
import matplotlib.pyplot as plt
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()
```



```
<Figure size 432x288 with 0 Axes>
```



Evaluating the model on the test set

```
test_model = keras.models.load_model("convnet_from_scratch.keras")
test_loss, test_acc = test_model.evaluate(test_dataset)
print(f"Test accuracy: {test_acc:.3f}")
```

```
32/32 [==============================] - 2s 46ms/step - loss: 0.5640 - accuracy: 0.7210
Test accuracy: 0.721
```

Here we got training accurracy as 97.95%, validation accuracy as 76.1% and test accuracy 72.1%

Question 2

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?

Using data augmentation

Define a data augmentation stage to add to an image model

```
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:
            shutil.copyfile(src=original_dir / fname,
                            dst=dir / fname)
#Here I have increased training sample size to 1500 and keeping the validation and test sample size to 500 each as before
make_subset("train", start_index=0, end_index=1500)
make_subset("validation", start_index=1500, end_index=2000)
make_subset("test", start_index=2000, end_index=2500)
```

```
data_augmentation = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
)
```

```
plt.figure(figsize=(10, 10))
for images, _ in train_dataset.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")
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:5 out of the last 5 calls to <function pfor.<locals>.f at 0x7f5fb048f0d0> triggered tf.function retracing. Tracing is
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:6 out of the last 6 calls to <function pfor.<locals>.f at 0x7f5fb048f040> triggered tf.function retracing. Tracing is
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
```

```
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
```

Defining a new convnet that includes image augmentation and dropout

```
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="rmsprop",
              metrics=["accuracy"])
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
```

```
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
```

Training the regularized convnet

```
callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch_with_augmentation.keras",
        save_best_only=True,
        monitor="val_loss")
]
history = model.fit(
    train_dataset,
    epochs=20,
    validation_data=validation_dataset,
    callbacks=callbacks)
```

```
Epoch 1/20
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
63/63 [==============================] - 18s 213ms/step - loss: 0.6962 - accuracy: 0.5030 - val_loss: 0.6929 - val_accuracy: 0.5000
Epoch 2/20
63/63 [==============================] - 14s 216ms/step - loss: 0.6934 - accuracy: 0.5055 - val_loss: 0.6918 - val_accuracy: 0.5340
Epoch 3/20
63/63 [==============================] - 16s 252ms/step - loss: 0.6888 - accuracy: 0.5575 - val_loss: 0.7942 - val_accuracy: 0.5030
Epoch 4/20
63/63 [==============================] - 16s 244ms/step - loss: 0.6912 - accuracy: 0.5750 - val_loss: 0.6571 - val_accuracy: 0.6350
Epoch 5/20
63/63 [==============================] - 14s 212ms/step - loss: 0.6541 - accuracy: 0.6330 - val_loss: 0.6311 - val_accuracy: 0.6460
Epoch 6/20
63/63 [==============================] - 13s 209ms/step - loss: 0.6369 - accuracy: 0.6385 - val_loss: 0.6825 - val_accuracy: 0.5690
Epoch 7/20
63/63 [==============================] - 15s 241ms/step - loss: 0.6359 - accuracy: 0.6490 - val_loss: 0.6193 - val_accuracy: 0.6630
Epoch 8/20
63/63 [==============================] - 15s 230ms/step - loss: 0.6148 - accuracy: 0.6560 - val_loss: 0.6224 - val_accuracy: 0.6480
Epoch 9/20
63/63 [==============================] - 15s 234ms/step - loss: 0.5992 - accuracy: 0.6705 - val_loss: 0.5958 - val_accuracy: 0.6980
Epoch 10/20
63/63 [==============================] - 14s 211ms/step - loss: 0.5982 - accuracy: 0.6760 - val_loss: 0.5950 - val_accuracy: 0.6750
Epoch 11/20
63/63 [==============================] - 14s 217ms/step - loss: 0.5687 - accuracy: 0.7215 - val_loss: 0.6038 - val_accuracy: 0.6860
Epoch 12/20
63/63 [==============================] - 15s 237ms/step - loss: 0.5611 - accuracy: 0.7130 - val_loss: 0.5695 - val_accuracy: 0.7120
Epoch 13/20
63/63 [==============================] - 15s 218ms/step - loss: 0.5571 - accuracy: 0.7095 - val_loss: 0.6388 - val_accuracy: 0.6720
Epoch 14/20
63/63 [==============================] - 15s 233ms/step - loss: 0.5411 - accuracy: 0.7345 - val_loss: 0.5674 - val_accuracy: 0.7050
Epoch 15/20
63/63 [==============================] - 13s 210ms/step - loss: 0.5261 - accuracy: 0.7460 - val_loss: 0.5793 - val_accuracy: 0.6970
Epoch 16/20
63/63 [==============================] - 14s 219ms/step - loss: 0.5223 - accuracy: 0.7460 - val_loss: 0.6557 - val_accuracy: 0.6840
Epoch 17/20
63/63 [==============================] - 14s 224ms/step - loss: 0.5137 - accuracy: 0.7555 - val_loss: 0.5148 - val_accuracy: 0.7410
Epoch 18/20
63/63 [==============================] - 13s 209ms/step - loss: 0.5014 - accuracy: 0.7515 - val_loss: 0.5885 - val_accuracy: 0.7090
Epoch 19/20
```

Evaluating the model on the test set

```
test_model = keras.models.load_model(
    "convnet_from_scratch_with_augmentation.keras")
test_loss, test_acc = test_model.evaluate(test_dataset)
print(f"Test accuracy: {test_acc:.3f}")
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
32/32 [==============================] - 1s 29ms/step - loss: 0.6054 - accuracy: 0.7380
Test accuracy: 0.738
```

Question 3

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.

```
original_dir = pathlib.Path("train")
new_base_dir = pathlib.Path("cats_vs_dogs_small_Q3")

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:
            shutil.copyfile(src=original_dir / fname,
                            dst=dir / fname)
#As increasing the sample size is always good than decreasing, here we're increasing the training the sample size to 2000
make_subset("train", start_index=0, end_index=2000)
#validation and test sample size 500 each
make_subset("validation", start_index=2000, end_index=2500)
make_subset("test", start_index=2500, end_index=3000)
```

```
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"])
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
```

```
callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch_with_augmentation1.keras",
        save_best_only=True,
        monitor="val_loss")
]
history = model.fit(
    train_dataset,
    epochs=20,
    validation_data=validation_dataset,
    callbacks=callbacks)
```

```
Epoch 1/20
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
63/63 [==============================] - 20s 227ms/step - loss: 0.6967 - accuracy: 0.4855 - val_loss: 0.6910 - val_accuracy: 0.5010
Epoch 2/20
63/63 [==============================] - 14s 212ms/step - loss: 0.6866 - accuracy: 0.5600 - val_loss: 0.6708 - val_accuracy: 0.5890
Epoch 3/20
63/63 [==============================] - 14s 211ms/step - loss: 0.6686 - accuracy: 0.5895 - val_loss: 0.6593 - val_accuracy: 0.6070
Epoch 4/20
63/63 [==============================] - 17s 262ms/step - loss: 0.6625 - accuracy: 0.5965 - val_loss: 0.6532 - val_accuracy: 0.6110
Epoch 5/20
63/63 [==============================] - 14s 220ms/step - loss: 0.6396 - accuracy: 0.6475 - val_loss: 0.6371 - val_accuracy: 0.6270
Epoch 6/20
63/63 [==============================] - 13s 210ms/step - loss: 0.6394 - accuracy: 0.6350 - val_loss: 0.6686 - val_accuracy: 0.5900
Epoch 7/20
63/63 [==============================] - 14s 223ms/step - loss: 0.6551 - accuracy: 0.6155 - val_loss: 0.6310 - val_accuracy: 0.6410
Epoch 8/20
63/63 [==============================] - 16s 249ms/step - loss: 0.6433 - accuracy: 0.6390 - val_loss: 0.7204 - val_accuracy: 0.5450
```

```
Epoch 9/20
63/63 [==============================] - 14s 225ms/step - loss: 0.6387 - accuracy: 0.6370 - val_loss: 0.6189 - val_accuracy: 0.6500
Epoch 10/20
63/63 [==============================] - 14s 216ms/step - loss: 0.6098 - accuracy: 0.6785 - val_loss: 0.5748 - val_accuracy: 0.6970
Epoch 11/20
63/63 [==============================] - 13s 208ms/step - loss: 0.5847 - accuracy: 0.6990 - val_loss: 0.5653 - val_accuracy: 0.6980
Epoch 12/20
63/63 [==============================] - 14s 214ms/step - loss: 0.5654 - accuracy: 0.7205 - val_loss: 0.5565 - val_accuracy: 0.7010
Epoch 13/20
63/63 [==============================] - 14s 211ms/step - loss: 0.5666 - accuracy: 0.7050 - val_loss: 0.5547 - val_accuracy: 0.7100
Epoch 14/20
63/63 [==============================] - 15s 226ms/step - loss: 0.5180 - accuracy: 0.7505 - val_loss: 0.5653 - val_accuracy: 0.7090
Epoch 15/20
63/63 [==============================] - 14s 213ms/step - loss: 0.5196 - accuracy: 0.7400 - val_loss: 0.5125 - val_accuracy: 0.7440
Epoch 16/20
63/63 [==============================] - 14s 212ms/step - loss: 0.5139 - accuracy: 0.7535 - val_loss: 0.5090 - val_accuracy: 0.7500
Epoch 17/20
63/63 [==============================] - 15s 225ms/step - loss: 0.5049 - accuracy: 0.7520 - val_loss: 0.5033 - val_accuracy: 0.7510
Epoch 18/20
63/63 [==============================] - 15s 242ms/step - loss: 0.4719 - accuracy: 0.7750 - val_loss: 0.5131 - val_accuracy: 0.7440
Epoch 19/20
```

```
test_model = keras.models.load_model(
    "convnet_from_scratch_with_augmentation1.keras")
test_loss, test_acc = test_model.evaluate(test_dataset)
print(f"Test accuracy: {test_acc:.3f}")
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
32/32 [==============================] - 1s 29ms/step - loss: 0.5207 - accuracy: 0.7510
Test accuracy: 0.751
```

Question 4

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.

Leveraging a pretrained model

Feature extraction with a pretrained model

Initiating the VGG16 convolutional base

```
conv_base = keras.applications.vgg16.VGG16(
    weights="imagenet",
    include_top=False,
    input_shape=(180, 180, 3))
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.
58889256/58889256 [==============================] - 0s 0us/step
```

```
conv_base.summary()
```

```
Model: "vgg16"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 input_5 (InputLayer)        [(None, 180, 180, 3)]     0         
                                                                 
 block1_conv1 (Conv2D)       (None, 180, 180, 64)      1792      
                                                                 
 block1_conv2 (Conv2D)       (None, 180, 180, 64)      36928     
                                                                 
 block1_pool (MaxPooling2D)  (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: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
```

Fast feature extraction without data augmentation.

Extracting the VGG16 features and corresponding labels

```
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 = conv_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(train_dataset)
val_features, val_labels =  get_features_and_labels(validation_dataset)
test_features, test_labels =  get_features_and_labels(test_dataset)
```

```
1/1 [==============================] - 2s 2s/step
1/1 [==============================] - 0s 44ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 31ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
```

```
1/1 [==============================] - 0s 31ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 32ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 33ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 47ms/step
1/1 [==============================] - 0s 35ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 41ms/step
1/1 [==============================] - 0s 42ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 34ms/step
1/1 [==============================] - 0s 38ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 31ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 26ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 24ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 25ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 26ms/step
```

```
train_features.shape
```

```
(2000, 5, 5, 512)
```

Defining and training the densely connected classifier

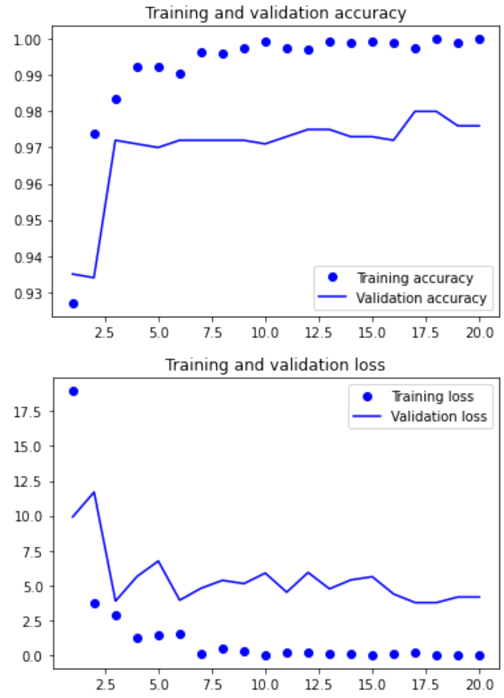
```
inputs = keras.Input(shape=(5, 5, 512))
x = layers.Flatten()(inputs)
x = layers.Dense(256)(x)
x = layers.Dropout(0.5)(x)
outputs = layers.Dense(1, activation="sigmoid")(x)
model = keras.Model(inputs, outputs)
model.compile(loss="binary_crossentropy",
              optimizer="rmsprop",
              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 10ms/step - loss: 18.9551 - accuracy: 0.9270 - val_loss: 9.9199 - val_accuracy: 0.9350
Epoch 2/20
63/63 [==============================] - 0s 5ms/step - loss: 3.6992 - accuracy: 0.9740 - val_loss: 11.6989 - val_accuracy: 0.9340
Epoch 3/20
63/63 [==============================] - 0s 7ms/step - loss: 2.8605 - accuracy: 0.9835 - val_loss: 3.8736 - val_accuracy: 0.9720
Epoch 4/20
63/63 [==============================] - 0s 6ms/step - loss: 1.2347 - accuracy: 0.9925 - val_loss: 5.6308 - val_accuracy: 0.9710
Epoch 5/20
63/63 [==============================] - 0s 6ms/step - loss: 1.3904 - accuracy: 0.9925 - val_loss: 6.7464 - val_accuracy: 0.9700
Epoch 6/20
63/63 [==============================] - 0s 5ms/step - loss: 1.5087 - accuracy: 0.9905 - val_loss: 3.9349 - val_accuracy: 0.9720
Epoch 7/20
63/63 [==============================] - 0s 5ms/step - loss: 0.1161 - accuracy: 0.9965 - val_loss: 4.7942 - val_accuracy: 0.9720
Epoch 8/20
63/63 [==============================] - 0s 5ms/step - loss: 0.4870 - accuracy: 0.9960 - val_loss: 5.3613 - val_accuracy: 0.9720
Epoch 9/20
63/63 [==============================] - 0s 7ms/step - loss: 0.3230 - accuracy: 0.9975 - val_loss: 5.1249 - val_accuracy: 0.9720
Epoch 10/20
63/63 [==============================] - 0s 5ms/step - loss: 0.0159 - accuracy: 0.9995 - val_loss: 5.8813 - val_accuracy: 0.9710
Epoch 11/20
63/63 [==============================] - 0s 6ms/step - loss: 0.1622 - accuracy: 0.9975 - val_loss: 4.5090 - val_accuracy: 0.9730
Epoch 12/20
63/63 [==============================] - 0s 6ms/step - loss: 0.2284 - accuracy: 0.9970 - val_loss: 5.9248 - val_accuracy: 0.9750
Epoch 13/20
63/63 [==============================] - 0s 5ms/step - loss: 0.0419 - accuracy: 0.9995 - val_loss: 4.7477 - val_accuracy: 0.9750
Epoch 14/20
63/63 [==============================] - 0s 5ms/step - loss: 0.1353 - accuracy: 0.9990 - val_loss: 5.3939 - val_accuracy: 0.9730
Epoch 15/20
63/63 [==============================] - 0s 7ms/step - loss: 0.0077 - accuracy: 0.9995 - val_loss: 5.6219 - val_accuracy: 0.9730
Epoch 16/20
63/63 [==============================] - 1s 15ms/step - loss: 0.0611 - accuracy: 0.9990 - val_loss: 4.3762 - val_accuracy: 0.9720
Epoch 17/20
63/63 [==============================] - 1s 9ms/step - loss: 0.1487 - accuracy: 0.9975 - val_loss: 3.7617 - val_accuracy: 0.9800
Epoch 18/20
63/63 [==============================] - 1s 8ms/step - loss: 0.0000e+00 - accuracy: 1.0000 - val_loss: 3.7617 - val_accuracy: 0.9800
Epoch 19/20
63/63 [==============================] - 0s 6ms/step - loss: 0.0290 - accuracy: 0.9990 - val_loss: 4.1654 - val_accuracy: 0.9760
Epoch 20/20
63/63 [==============================] - 0s 6ms/step - loss: 3.7300e-17 - accuracy: 1.0000 - val_loss: 4.1654 - val_accuracy: 0.9760
```

Plotting the results

```
import matplotlib.pyplot as plt
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 together with data augmentation.

Initiating and freezing the VGG16 convolutional base

```
conv_base  = keras.applications.vgg16.VGG16(
    weights="imagenet",
    include_top=False)
conv_base.trainable = False
```

Printing the list of trainable weights before and after freezing

```
conv_base.trainable = True
print("This is the number of trainable weights "
      "before freezing the conv base:", len(conv_base.trainable_weights))
```

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

```
conv_base.trainable = False
print("This is the number of trainable weights "
      "after freezing the conv base:", len(conv_base.trainable_weights))
```

```
     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

```
data_augmentation = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
)

inputs = keras.Input(shape=(180, 180, 3))
x = data_augmentation(inputs)
```

```
x = keras.applications.vgg16.preprocess_input(x)
x = conv_base(x)
x = layers.Flatten()(x)
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"])
```

```
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
```

```
callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="feature_extraction_with_data_augmentation.keras",
        save_best_only=True,
        monitor="val_loss")
]
history = model.fit(
    train_dataset,
    epochs=10,
    validation_data=validation_dataset,
    callbacks=callbacks)
```

```
Epoch 1/10
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting RngReadAndSkip cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting Bitcast cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting StatelessRandomUniformV2 cause there is no registered converter for this op.
WARNING:tensorflow:Using a while_loop for converting ImageProjectiveTransformV3 cause there is no registered converter for this op.
63/63 [==============================] - 23s 299ms/step - loss: 19.6682 - accuracy: 0.8935 - val_loss: 3.5151 - val_accuracy: 0.9640
Epoch 2/10
63/63 [==============================] - 18s 282ms/step - loss: 7.8176 - accuracy: 0.9420 - val_loss: 3.5388 - val_accuracy: 0.9700
Epoch 3/10
63/63 [==============================] - 18s 281ms/step - loss: 5.4542 - accuracy: 0.9630 - val_loss: 6.7396 - val_accuracy: 0.9570
Epoch 4/10
63/63 [==============================] - 22s 347ms/step - loss: 5.0911 - accuracy: 0.9625 - val_loss: 4.9181 - val_accuracy: 0.9700
Epoch 5/10
63/63 [==============================] - 19s 302ms/step - loss: 2.5755 - accuracy: 0.9715 - val_loss: 12.2249 - val_accuracy: 0.9490
Epoch 6/10
63/63 [==============================] - 20s 321ms/step - loss: 3.3433 - accuracy: 0.9740 - val_loss: 4.7799 - val_accuracy: 0.9740
Epoch 7/10
63/63 [==============================] - 18s 291ms/step - loss: 2.9975 - accuracy: 0.9715 - val_loss: 4.4656 - val_accuracy: 0.9730
Epoch 8/10
63/63 [==============================] - 18s 282ms/step - loss: 2.4532 - accuracy: 0.9785 - val_loss: 2.4683 - val_accuracy: 0.9790
Epoch 9/10
63/63 [==============================] - 18s 282ms/step - loss: 1.2511 - accuracy: 0.9825 - val_loss: 7.2630 - val_accuracy: 0.9650
```