assignment-2

October 20, 2024

```python
[ ]: from google.colab import files
     files.upload()
```

```
<IPython.core.display.HTML object>

Saving dogs-vs-cats.zip to dogs-vs-cats.zip
```

```python
[7]: from google.colab import drive
     drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```python
[8]: !unzip /content/drive/MyDrive/dogs-vs-cats.zip
```

```
Archive:  /content/drive/MyDrive/dogs-vs-cats.zip
  inflating: sampleSubmission.csv
  inflating: test1.zip
  inflating: train.zip
```

```python
[9]: !unzip /content/train.zip
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Streaming output truncated to the last 5000 lines.
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inflating: train/dog.9984.jpg
inflating: train/dog.9985.jpg
inflating: train/dog.9986.jpg
inflating: train/dog.9987.jpg
inflating: train/dog.9988.jpg
inflating: train/dog.9989.jpg
inflating: train/dog.999.jpg
inflating: train/dog.9990.jpg
inflating: train/dog.9991.jpg
inflating: train/dog.9992.jpg
inflating: train/dog.9993.jpg
inflating: train/dog.9994.jpg
inflating: train/dog.9995.jpg
inflating: train/dog.9996.jpg
inflating: train/dog.9997.jpg
inflating: train/dog.9998.jpg
inflating: train/dog.9999.jpg
```

```python
[38]: import os, shutil, pathlib

      src_dir_ = pathlib.Path("train")
      tgt_base_dir = pathlib.Path("cats_vs_dogs_small_1")

      def creatingSubset(setType, idx_start, idx_end):
          for a in ("cat", "dog"):
```

```
        sub_dir = tgt_base_dir / setType / a
        os.makedirs(sub_dir)
        names_file = [f"{a}.{i}.jpg" for i in range(idx_start, idx_end)]
        for name_file in names_file:
            shutil.copyfile(src=src_dir_ / name_file,
                            dst=sub_dir / name_file)

creatingSubset("data_training", idx_start=0, idx_end=1000)
creatingSubset("data_validation", idx_start=1000, idx_end=1500)
creatingSubset("data_testing", idx_start=1500, idx_end=2000)
```

[39]:
```python
from tensorflow import keras
from tensorflow.keras import layers

ipt = keras.Input(shape=(180, 180, 3))
z = layers.Rescaling(1./255)(ipt)
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)
```

[40]: `mdl.summary()`

```
Model: "functional_7"


 Layer (type)                        Output Shape                        ␣
 ↪Param #

 input_layer_4 (InputLayer)          (None, 180, 180, 3)                 ␣
 ↪  0

 rescaling_3 (Rescaling)             (None, 180, 180, 3)                 ␣
 ↪  0

 conv2d_15 (Conv2D)                  (None, 178, 178, 32)                ␣
 ↪896
```

```
max_pooling2d_12 (MaxPooling2D)        (None, 89, 89, 32)                    ␣
↳   0

conv2d_16 (Conv2D)                     (None, 87, 87, 64)                    ␣
↳18,496

max_pooling2d_13 (MaxPooling2D)        (None, 43, 43, 64)                    ␣
↳   0

conv2d_17 (Conv2D)                     (None, 41, 41, 128)                   ␣
↳73,856

max_pooling2d_14 (MaxPooling2D)        (None, 20, 20, 128)                   ␣
↳   0

conv2d_18 (Conv2D)                     (None, 18, 18, 256)                   ␣
↳295,168

max_pooling2d_15 (MaxPooling2D)        (None, 9, 9, 256)                     ␣
↳   0

conv2d_19 (Conv2D)                     (None, 7, 7, 256)                     ␣
↳590,080

flatten_3 (Flatten)                    (None, 12544)                         ␣
↳   0

dense_3 (Dense)                        (None, 1)                             ␣
↳12,545
```

Total params: 991,041 (3.78 MB)

Trainable params: 991,041 (3.78 MB)

Non-trainable params: 0 (0.00 B)

```
[41]: mdl.compile(loss="binary_crossentropy",
                optimizer="rmsprop",
                metrics=["accuracy"])
```

To prevent overfitting, we apply regularization techniques during the data preprocessing stage. At this point, each image is converted into a tensor.

```python
[42]: from tensorflow.keras.utils import image_dataset_from_directory

      data_dataset_training = image_dataset_from_directory(
          tgt_base_dir / "data_training",
          image_size=(180, 180),
          batch_size=32)

      data_dataset_validation = image_dataset_from_directory(
          tgt_base_dir / "data_validation",
          image_size=(180, 180),
          batch_size=32)

      data_dataset_testing = image_dataset_from_directory(
          tgt_base_dir / "data_testing",
          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.
```

Callbacks can be used to stop training early if the model does not progress or to save the model's weights after each epoch. They can also help to control the learning rate, record metrics, and visualize the model's performance.

```python
[44]: from tensorflow import keras

      callbacks = [
          keras.callbacks.ModelCheckpoint(
              filepath="convnet_from_scratch1.keras",
              save_best_only=True,
              monitor="val_loss"
          )
      ]

      history = mdl.fit(
          data_dataset_training,
          epochs=10,
          validation_data=data_dataset_validation,
          callbacks=callbacks
      )
```

```
Epoch 1/10
63/63                8s 91ms/step -
accuracy: 0.5302 - loss: 0.6936 - val_accuracy: 0.5000 - val_loss: 0.6934
Epoch 2/10
63/63                6s 91ms/step -
accuracy: 0.5367 - loss: 0.6960 - val_accuracy: 0.5160 - val_loss: 0.6917
```

```
Epoch 3/10
63/63                4s 64ms/step -
accuracy: 0.5392 - loss: 0.6921 - val_accuracy: 0.6060 - val_loss: 0.6659
Epoch 4/10
63/63                4s 54ms/step -
accuracy: 0.6231 - loss: 0.6824 - val_accuracy: 0.6530 - val_loss: 0.6228
Epoch 5/10
63/63                7s 91ms/step -
accuracy: 0.6543 - loss: 0.6294 - val_accuracy: 0.6140 - val_loss: 0.6386
Epoch 6/10
63/63                8s 52ms/step -
accuracy: 0.6872 - loss: 0.5897 - val_accuracy: 0.6110 - val_loss: 0.6544
Epoch 7/10
63/63                7s 77ms/step -
accuracy: 0.7146 - loss: 0.5559 - val_accuracy: 0.6800 - val_loss: 0.5787
Epoch 8/10
63/63                5s 76ms/step -
accuracy: 0.7444 - loss: 0.5208 - val_accuracy: 0.6440 - val_loss: 0.6314
Epoch 9/10
63/63                4s 58ms/step -
accuracy: 0.7572 - loss: 0.4942 - val_accuracy: 0.7110 - val_loss: 0.5876
Epoch 10/10
63/63                5s 55ms/step -
accuracy: 0.7740 - loss: 0.5100 - val_accuracy: 0.7160 - val_loss: 0.5668
```

As the number of epochs increases, the accuracy tends to rise, with values reaching 77.4% for training accuracy, 71.60% for validation accuracy, and 69% for test accuracy.

```python
[99]: import matplotlib.pyplot as plt
      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, "go", label="Training accuracy")
      plt.plot(epochs, val_accuracy, "g", label="Validation accuracy")
      plt.title("Training and validation accuracy")
      plt.legend()
      plt.figure()
      plt.plot(epochs, loss, "ro", label="Training loss")
      plt.plot(epochs, val_loss, "r", label="Validation loss")
      plt.title("Training and validation loss")
      plt.legend()
      plt.show()
```

Training and validation accuracy

Training and validation loss
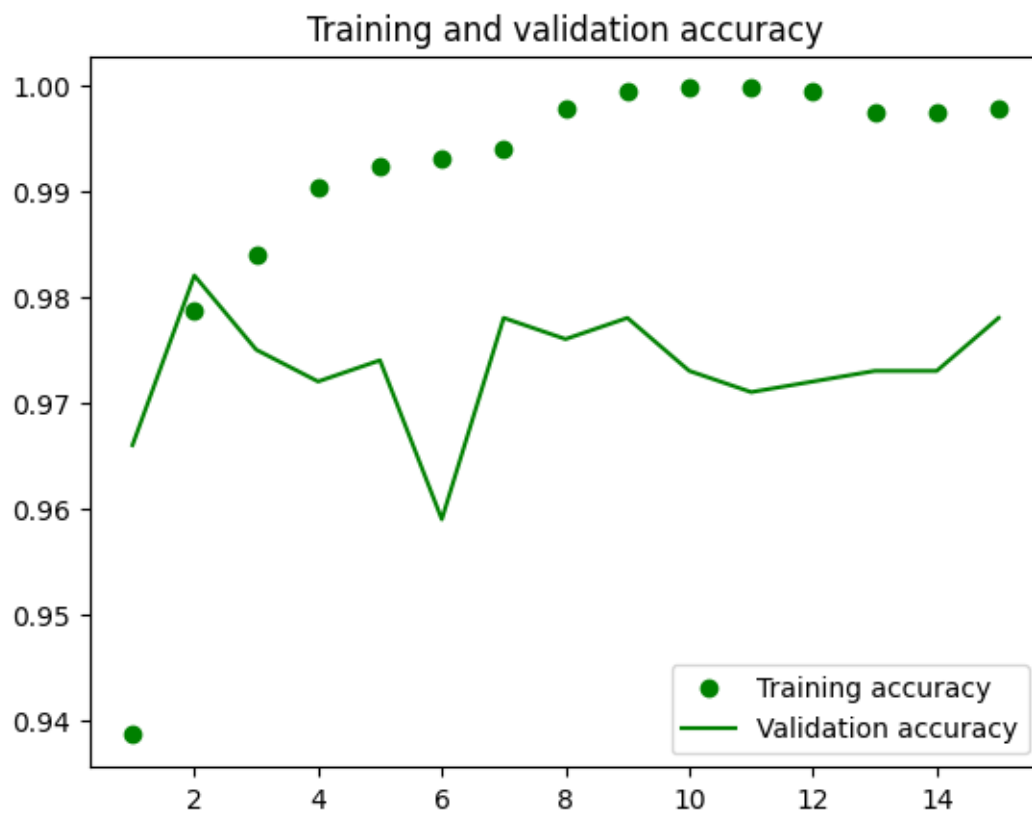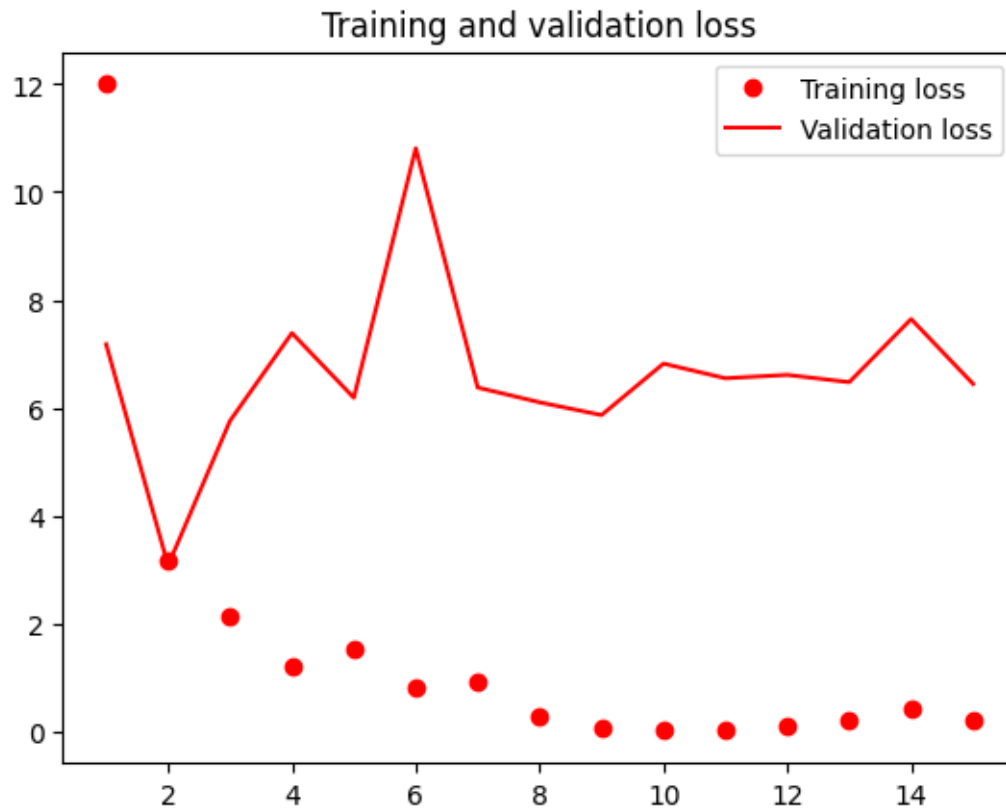

```
[51]:  test_mdl = keras.models.load_model("convnet_from_scratch1.keras")
       test_lossVal, test_acc_Value = test_mdl.evaluate(data_dataset_testing)
       print(f"Test accuracy: {test_acc_Value:.3f}")
```

```
32/32                 2s 43ms/step -
accuracy: 0.6861 - loss: 0.5986
Test accuracy: 0.690
```

Test accuracy with no data augmentation=69%

Data Augmentation

Data augmentation is a strategy for increasing the size of a training set by generating new, modified versions of the original data. This reduces overfitting and improves the model's generalizability.

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

111

```
from keras.preprocessing.image import load_img

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



```
ipt = keras.Input(shape=(180, 180, 3))
z = aug_data(ipt)
z = layers.Rescaling(1./255)(z)
```

```
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
z = layers.Dropout(0.5)(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)

mdl.compile(loss="binary_crossentropy",
            optimizer="rmsprop",
            metrics=["accuracy"])
```

```
[48]: callbacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch_with_augmentation1.keras",
        save_best_only=True,
        monitor="val_loss"
    )
]

history = mdl.fit(
    data_dataset_training,
    epochs=10,
    validation_data=data_dataset_validation,
    callbacks=callbacks
)
```

```
Epoch 1/10
63/63              5s 60ms/step -
accuracy: 0.4917 - loss: 0.7111 - val_accuracy: 0.5000 - val_loss: 0.6924
Epoch 2/10
63/63              7s 89ms/step -
accuracy: 0.5252 - loss: 0.6945 - val_accuracy: 0.6270 - val_loss: 0.6890
Epoch 3/10
63/63              5s 72ms/step -
accuracy: 0.5615 - loss: 0.6820 - val_accuracy: 0.5370 - val_loss: 0.6787
Epoch 4/10
63/63              4s 57ms/step -
accuracy: 0.5979 - loss: 0.6592 - val_accuracy: 0.5350 - val_loss: 0.6816
Epoch 5/10
63/63              7s 87ms/step -
```

```
accuracy: 0.6467 - loss: 0.6486 - val_accuracy: 0.6370 - val_loss: 0.6326
Epoch 6/10
63/63              8s 55ms/step -
accuracy: 0.6575 - loss: 0.6418 - val_accuracy: 0.6190 - val_loss: 0.6848
Epoch 7/10
63/63              7s 87ms/step -
accuracy: 0.6728 - loss: 0.6051 - val_accuracy: 0.6230 - val_loss: 0.6404
Epoch 8/10
63/63              4s 70ms/step -
accuracy: 0.6678 - loss: 0.6108 - val_accuracy: 0.5330 - val_loss: 1.1451
Epoch 9/10
63/63              5s 62ms/step -
accuracy: 0.6780 - loss: 0.6234 - val_accuracy: 0.6800 - val_loss: 0.5946
Epoch 10/10
63/63              4s 57ms/step -
accuracy: 0.7038 - loss: 0.5748 - val_accuracy: 0.6560 - val_loss: 0.5931
```

[53]:
```python
test_mdl = keras.models.load_model(
    "convnet_from_scratch_with_augmentation1.keras"
)
test_lossVal, test_acc_Value = test_mdl.evaluate(data_dataset_testing)
print(f"Test accuracy: {test_acc_Value:.3f}")
```

```
32/32              1s 29ms/step -
accuracy: 0.6296 - loss: 0.6313
Test accuracy: 0.623
```

Although doing data augmentation on the model did not result in improved results, it is still possible to verify this by trying data augmentation on a larger training sample.

accuracy=70.38% val_acc=65.60% test_acc=62.3%

Test accuracy was not improved

2.Increase training sample size

Attempted to increase training sample size from 1000 to 1500.

[54]:
```python
import os
import shutil
import pathlib

src_dir_ = pathlib.Path("train")
tgt_base_dir = pathlib.Path("cats_vs_dogs_small_2")

def create_subSet(setType, idx_start, idx_end):
    for a in ("cat", "dog"):
        sub_dir = tgt_base_dir / setType / a
        os.makedirs(sub_dir, exist_ok=True)
        names_file = [f"{a}.{i}.jpg" for i in range(idx_start, idx_end)]
```

```
            for fname in names_file:
                shutil.copyfile(src=src_dir_ / fname,
                                dst=sub_dir / fname)

create_subSet("data_training", idx_start=0, idx_end=1500)
create_subSet("data_validation", idx_start=1500, idx_end=2000)
create_subSet("data_testing", idx_start=2000, idx_end=2500)
```

[55]:
```python
from tensorflow.keras.utils import image_dataset_from_directory

data_dataset_training = image_dataset_from_directory(
    tgt_base_dir / "data_training",
    image_size=(180, 180),
    batch_size=32
)

data_dataset_validation = image_dataset_from_directory(
    tgt_base_dir / "data_validation",
    image_size=(180, 180),
    batch_size=32
)

data_dataset_testing = image_dataset_from_directory(
    tgt_base_dir / "data_testing",
    image_size=(180, 180),
    batch_size=32
)
```

```
Found 3000 files belonging to 2 classes.
Found 1000 files belonging to 2 classes.
Found 1000 files belonging to 2 classes.
```

[56]:
```python
ipt = keras.Input(shape=(180, 180, 3))
z = layers.Rescaling(1./255)(ipt)
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)
```

```
mdl.compile(loss="binary_crossentropy",
            optimizer="rmsprop",
            metrics=["accuracy"])
```

[57]:
```
_callBacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch2.keras",
        save_best_only=True,
        monitor="val_loss"
    )
]

history = mdl.fit(
    data_dataset_training,
    epochs=10,
    validation_data=data_dataset_validation,
    callbacks=_callBacks
)
```

```
Epoch 1/10
94/94              13s 119ms/step -
accuracy: 0.5064 - loss: 0.6966 - val_accuracy: 0.5030 - val_loss: 0.6922
Epoch 2/10
94/94              5s 57ms/step -
accuracy: 0.5702 - loss: 0.6828 - val_accuracy: 0.6130 - val_loss: 0.7441
Epoch 3/10
94/94              10s 59ms/step -
accuracy: 0.6364 - loss: 0.6482 - val_accuracy: 0.6610 - val_loss: 0.6281
Epoch 4/10
94/94              12s 73ms/step -
accuracy: 0.6776 - loss: 0.6035 - val_accuracy: 0.5420 - val_loss: 0.8883
Epoch 5/10
94/94              5s 58ms/step -
accuracy: 0.7144 - loss: 0.5781 - val_accuracy: 0.6970 - val_loss: 0.6717
Epoch 6/10
94/94              14s 94ms/step -
accuracy: 0.7398 - loss: 0.5373 - val_accuracy: 0.7040 - val_loss: 0.6013
Epoch 7/10
94/94              6s 51ms/step -
accuracy: 0.7603 - loss: 0.4952 - val_accuracy: 0.7010 - val_loss: 0.6243
Epoch 8/10
94/94              5s 54ms/step -
accuracy: 0.7977 - loss: 0.4350 - val_accuracy: 0.6880 - val_loss: 0.7075
Epoch 9/10
94/94              7s 72ms/step -
accuracy: 0.8194 - loss: 0.4044 - val_accuracy: 0.7360 - val_loss: 0.6447
Epoch 10/10
```

```
94/94                  5s 52ms/step -
accuracy: 0.8459 - loss: 0.3602 - val_accuracy: 0.7540 - val_loss: 0.5905
```

[58]:
```python
mdl_test = keras.models.load_model(
    "convnet_from_scratch2.keras"
)
lossVal_test, acc_Value_test = mdl_test.evaluate(data_dataset_testing)
print(f"Test accuracy: {acc_Value_test:.3f}")
```

```
32/32                  3s 61ms/step -
accuracy: 0.7802 - loss: 0.5795
Test accuracy: 0.785
```

Accuracy=84.59% val_acc=75.4% test_acc=78%

using data augmentation

[59]:
```python
aug_data = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
)
```

[60]:
```python
ipt = keras.Input(shape=(180, 180, 3))
z = aug_data(ipt)
z = layers.Rescaling(1./255)(z)
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
z = layers.Dropout(0.5)(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)

mdl.compile(loss="binary_crossentropy",
            optimizer="adam",
            metrics=["accuracy"])
```

[61]:
```python
_callBacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch_with_augmentation2.keras",
```

```
        save_best_only=True,
        monitor="val_loss"
    )
]

history = mdl.fit(
    data_dataset_training,
    epochs=10,
    validation_data=data_dataset_validation,
    callbacks=_callBacks
)
```

```
Epoch 1/10
94/94              12s 91ms/step -
accuracy: 0.5093 - loss: 0.6957 - val_accuracy: 0.5010 - val_loss: 0.6811
Epoch 2/10
94/94              6s 66ms/step -
accuracy: 0.5273 - loss: 0.6788 - val_accuracy: 0.5110 - val_loss: 0.7024
Epoch 3/10
94/94              7s 72ms/step -
accuracy: 0.5786 - loss: 0.6637 - val_accuracy: 0.6080 - val_loss: 0.7083
Epoch 4/10
94/94              10s 66ms/step -
accuracy: 0.6234 - loss: 0.6435 - val_accuracy: 0.6350 - val_loss: 0.6678
Epoch 5/10
94/94              7s 74ms/step -
accuracy: 0.6625 - loss: 0.6055 - val_accuracy: 0.6660 - val_loss: 0.6245
Epoch 6/10
94/94              6s 66ms/step -
accuracy: 0.7162 - loss: 0.5711 - val_accuracy: 0.6930 - val_loss: 0.5811
Epoch 7/10
94/94              5s 54ms/step -
accuracy: 0.6912 - loss: 0.5887 - val_accuracy: 0.6590 - val_loss: 0.6395
Epoch 8/10
94/94              10s 51ms/step -
accuracy: 0.7082 - loss: 0.5618 - val_accuracy: 0.7050 - val_loss: 0.6001
Epoch 9/10
94/94              6s 56ms/step -
accuracy: 0.7100 - loss: 0.5777 - val_accuracy: 0.7000 - val_loss: 0.6057
Epoch 10/10
94/94              9s 97ms/step -
accuracy: 0.7155 - loss: 0.5658 - val_accuracy: 0.7120 - val_loss: 0.5738
```

```
[64]: mdl_test = keras.models.load_model(
          "convnet_from_scratch_with_augmentation2.keras"
      )
      lossVal_test, acc_Value_test = mdl_test.evaluate(data_dataset_testing)
```

```
print(f"Test accuracy: {acc_Value_test:.3f}")
```

32/32   **1s 32ms/step -**
accuracy: 0.7418 - loss: 0.5273
Test accuracy: 0.743

Accuracy=71.5% val_acc=71.2% test_acc=4.3%

3.Finding the ideal training sample size

We set the training, validation, and test set sizes, respectively, to 1500, 1000, and 500

```python
[62]: import os
      import shutil
      import pathlib

      src_dir_ = pathlib.Path("train")
      tgt_base_dir = pathlib.Path("cats_vs_dogs_small_3")

      def create_subSet(setType, idx_start, idx_end):
          for a in ("cat", "dog"):
              sub_dir = tgt_base_dir / setType / a
              os.makedirs(sub_dir, exist_ok=True)
              names_file = [f"{a}.{i}.jpg" for i in range(idx_start, idx_end)]
              for fname in names_file:
                  shutil.copyfile(src=src_dir_ / fname, dst=sub_dir / fname)

      create_subSet("train", idx_start=0, idx_end=1500)
      create_subSet("validation", idx_start=1500, idx_end=2500)
      create_subSet("test", idx_start=2500, idx_end=3000)
```

```python
[65]: from tensorflow.keras.utils import image_dataset_from_directory

      data_dataset_training = image_dataset_from_directory(
          tgt_base_dir / "train",
          image_size=(180, 180),
          batch_size=32
      )

      data_dataset_validation = image_dataset_from_directory(
          tgt_base_dir / "validation",
          image_size=(180, 180),
          batch_size=32
      )

      data_dataset_testing = image_dataset_from_directory(
          tgt_base_dir / "test",
          image_size=(180, 180),
          batch_size=32
```

```
)
```

```
Found 3000 files belonging to 2 classes.
Found 2000 files belonging to 2 classes.
Found 1000 files belonging to 2 classes.
```

[66]:
```python
ipt = keras.Input(shape=(180, 180, 3))
z = layers.Rescaling(1./255)(ipt)
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)

mdl.compile(loss="binary_crossentropy",
            optimizer="rmsprop",
            metrics=["accuracy"])
```

[67]:
```python
_callBacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch3.keras",
        save_best_only=True,
        monitor="val_loss"
    )
]
history = mdl.fit(
    data_dataset_training,
    epochs=10,
    validation_data=data_dataset_validation,
    callbacks=_callBacks
)
```

```
Epoch 1/10
94/94              14s 112ms/step -
accuracy: 0.5175 - loss: 0.7080 - val_accuracy: 0.5025 - val_loss: 0.6905
Epoch 2/10
94/94              15s 73ms/step -
accuracy: 0.5602 - loss: 0.6904 - val_accuracy: 0.6435 - val_loss: 0.6552
Epoch 3/10
94/94              7s 76ms/step -
```

```
accuracy: 0.5883 - loss: 0.6670 - val_accuracy: 0.6575 - val_loss: 0.6284
Epoch 4/10
94/94                7s 76ms/step -
accuracy: 0.6388 - loss: 0.6345 - val_accuracy: 0.6890 - val_loss: 0.5858
Epoch 5/10
94/94                5s 58ms/step -
accuracy: 0.7108 - loss: 0.5804 - val_accuracy: 0.6880 - val_loss: 0.5756
Epoch 6/10
94/94                12s 81ms/step -
accuracy: 0.7057 - loss: 0.5595 - val_accuracy: 0.6075 - val_loss: 0.7807
Epoch 7/10
94/94                6s 67ms/step -
accuracy: 0.7394 - loss: 0.5244 - val_accuracy: 0.7320 - val_loss: 0.5315
Epoch 8/10
94/94                10s 106ms/step -
accuracy: 0.7561 - loss: 0.4974 - val_accuracy: 0.7515 - val_loss: 0.5317
Epoch 9/10
94/94                6s 65ms/step -
accuracy: 0.8029 - loss: 0.4247 - val_accuracy: 0.7625 - val_loss: 0.5408
Epoch 10/10
94/94                11s 72ms/step -
accuracy: 0.8267 - loss: 0.3746 - val_accuracy: 0.7540 - val_loss: 0.5279
```

[69]:
```python
mdl_test = keras.models.load_model(
    "convnet_from_scratch3.keras"
)
lossVal_test, acc_Value_test = mdl_test.evaluate(data_dataset_testing)
print(f"Test accuracy: {acc_Value_test:.3f}")
```

```
32/32                2s 39ms/step -
accuracy: 0.7904 - loss: 0.5144
Test accuracy: 0.759
```

Accuracy=82.67% val_Acc=75.4% test_Acc=75.9%

Using Data augmentation

[70]:
```python
aug_data = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
)
```

[71]:
```python
ipt = keras.Input(shape=(180, 180, 3))
z = aug_data(ipt)
z = layers.Rescaling(1./255)(z)
z = layers.Conv2D(filters=32, kernel_size=3, activation="relu")(z)
```

```
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=64, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=128, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.MaxPooling2D(pool_size=2)(z)
z = layers.Conv2D(filters=256, kernel_size=3, activation="relu")(z)
z = layers.Flatten()(z)
z = layers.Dropout(0.5)(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)

mdl.compile(loss="binary_crossentropy",
            optimizer="adam",
            metrics=["accuracy"])
```

[73]:
```
_callBacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="convnet_from_scratch_with_augmentation3.keras",
        save_best_only=True,
        monitor="val_loss")
]
history = mdl.fit(
    data_dataset_training,
    epochs=10,
    validation_data=data_dataset_validation,
    callbacks=_callBacks)
```

```
Epoch 1/10
94/94              11s 95ms/step -
accuracy: 0.5245 - loss: 0.6952 - val_accuracy: 0.5000 - val_loss: 0.6932
Epoch 2/10
94/94              7s 65ms/step -
accuracy: 0.4988 - loss: 0.6927 - val_accuracy: 0.5005 - val_loss: 0.6918
Epoch 3/10
94/94              10s 67ms/step -
accuracy: 0.5255 - loss: 0.6928 - val_accuracy: 0.5205 - val_loss: 0.6930
Epoch 4/10
94/94              6s 65ms/step -
accuracy: 0.5260 - loss: 0.6885 - val_accuracy: 0.6195 - val_loss: 0.6676
Epoch 5/10
94/94              10s 61ms/step -
accuracy: 0.5387 - loss: 0.6821 - val_accuracy: 0.5995 - val_loss: 0.6798
Epoch 6/10
94/94              13s 96ms/step -
accuracy: 0.5871 - loss: 0.6797 - val_accuracy: 0.6305 - val_loss: 0.6554
```

```
Epoch 7/10
94/94                  6s 61ms/step -
accuracy: 0.6099 - loss: 0.6562 - val_accuracy: 0.6385 - val_loss: 0.6393
Epoch 8/10
94/94                  11s 74ms/step -
accuracy: 0.6368 - loss: 0.6445 - val_accuracy: 0.6530 - val_loss: 0.6312
Epoch 9/10
94/94                  14s 113ms/step -
accuracy: 0.6345 - loss: 0.6454 - val_accuracy: 0.6345 - val_loss: 0.6602
Epoch 10/10
94/94                  6s 61ms/step -
accuracy: 0.6742 - loss: 0.6137 - val_accuracy: 0.6625 - val_loss: 0.6304
```

[74]:
```python
mdl_test = keras.models.load_model(
    "convnet_from_scratch_with_augmentation3.keras")
lossVal_test, acc_Value_test = mdl_test.evaluate(data_dataset_testing)
print(f"Test accuracy: {acc_Value_test:.3f}")
```

```
32/32                  2s 49ms/step -
accuracy: 0.6495 - loss: 0.6407
Test accuracy: 0.654
```

Accuracy=67.4% val_acc=66.2% test_acc=65.4%

4.Using a pre-trained network

VGG16 is the architecture of this pre-trained network.

Feature extraction - Instantiating the VGG16 convolutional base

[75]:
```python
ba_seConv = keras.applications.vgg16.VGG16(
    weights="imagenet",
    include_top=False,
    input_shape=(180, 180, 3)
)
ba_seConv.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-
applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58889256/58889256          0s
0us/step
```

Model: "vgg16"

```
 Layer (type)                       Output Shape                            ␣
 ↪Param #

 input_layer_13 (InputLayer)        (None, 180, 180, 3)                     ␣
 ↪   0
```

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```
block1_conv1 (Conv2D)                (None, 180, 180, 64)                 ␣
↪1,792

block1_conv2 (Conv2D)                (None, 180, 180, 64)                 ␣
↪36,928

block1_pool (MaxPooling2D)           (None, 90, 90, 64)                   ␣
↪   0

block2_conv1 (Conv2D)                (None, 90, 90, 128)                  ␣
↪73,856

block2_conv2 (Conv2D)                (None, 90, 90, 128)                  ␣
↪147,584

block2_pool (MaxPooling2D)           (None, 45, 45, 128)                  ␣
↪   0

block3_conv1 (Conv2D)                (None, 45, 45, 256)                  ␣
↪295,168

block3_conv2 (Conv2D)                (None, 45, 45, 256)                  ␣
↪590,080

block3_conv3 (Conv2D)                (None, 45, 45, 256)                  ␣
↪590,080

block3_pool (MaxPooling2D)           (None, 22, 22, 256)                  ␣
↪   0

block4_conv1 (Conv2D)                (None, 22, 22, 512)                  ␣
↪1,180,160

block4_conv2 (Conv2D)                (None, 22, 22, 512)                  ␣
↪2,359,808

block4_conv3 (Conv2D)                (None, 22, 22, 512)                  ␣
↪2,359,808

block4_pool (MaxPooling2D)           (None, 11, 11, 512)                  ␣
↪   0

block5_conv1 (Conv2D)                (None, 11, 11, 512)                  ␣
↪2,359,808
```

```
block5_conv2 (Conv2D)                    (None, 11, 11, 512)                        ⊔
↪2,359,808

block5_conv3 (Conv2D)                    (None, 11, 11, 512)                        ⊔
↪2,359,808

block5_pool (MaxPooling2D)               (None, 5, 5, 512)                            ⊔
↪   0
```

Total params: 14,714,688 (56.13 MB)

Trainable params: 14,714,688 (56.13 MB)

Non-trainable params: 0 (0.00 B)

Feature extraction - Extracting features and corresponding labels

```python
[76]: import numpy as np

def featuresAndLabels_Get(dataset):
    features_list = []
    labels_list = []
    for imgs, lbls in dataset:
        preprocessed_imgs = keras.applications.vgg16.preprocess_input(imgs)
        feature_set = ba_seConv.predict(preprocessed_imgs)
        features_list.append(feature_set)
        labels_list.append(lbls)
    return np.concatenate(features_list), np.concatenate(labels_list)

train_features, train_labels = featuresAndLabels_Get(train_dataset)
val_features, val_labels = featuresAndLabels_Get(validation_dataset)
test_features, test_labels = featuresAndLabels_Get(test_dataset)

train_features.shape
```

```
1/1                14s 14s/step
1/1                0s 27ms/step
1/1                0s 25ms/step
1/1                0s 25ms/step
1/1                0s 26ms/step
1/1                0s 28ms/step
1/1                0s 26ms/step
1/1                0s 26ms/step
1/1                0s 34ms/step
1/1                0s 32ms/step
```

```
1/1                    0s 27ms/step
1/1                    0s 21ms/step
1/1                    0s 25ms/step
1/1                    0s 25ms/step
1/1                    0s 25ms/step
1/1                    0s 41ms/step
1/1                    0s 21ms/step
1/1                    0s 24ms/step
1/1                    0s 30ms/step
1/1                    0s 25ms/step
1/1                    0s 22ms/step
1/1                    0s 25ms/step
1/1                    0s 21ms/step
1/1                    0s 25ms/step
1/1                    0s 28ms/step
1/1                    0s 25ms/step
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1/1                    0s 26ms/step
1/1                    0s 23ms/step
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1/1                    0s 23ms/step
1/1                    0s 22ms/step
1/1                    0s 23ms/step
1/1                    0s 29ms/step
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1/1                    0s 30ms/step
1/1                    0s 33ms/step
1/1                    0s 28ms/step
1/1                    0s 31ms/step
1/1                    0s 34ms/step
1/1                    0s 55ms/step
1/1                    0s 35ms/step
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1/1                    0s 41ms/step
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```

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1/1                 0s 31ms/step
1/1                 0s 22ms/step
1/1                 0s 21ms/step
1/1                 0s 27ms/step
1/1                 0s 21ms/step
1/1                 0s 21ms/step
1/1                 9s 9s/step
1/1                 0s 52ms/step
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```

```
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1/1                      0s 22ms/step
1/1                      0s 23ms/step
1/1                      0s 26ms/step
1/1                      0s 21ms/step
1/1                      0s 21ms/step
1/1                      0s 21ms/step
1/1                      0s 21ms/step
1/1                      0s 30ms/step
1/1                      0s 23ms/step
1/1                      0s 22ms/step
```

```
1/1                    0s 27ms/step
1/1                    0s 23ms/step
1/1                    0s 22ms/step
1/1                    0s 17ms/step
```

[76]: (3000, 5, 5, 512)

Feature extraction - Defining and training the densely connected classifier

```
[78]: ipt = keras.Input(shape=(5, 5, 512))
      z = layers.Flatten()(ipt)
      z = layers.Dense(256)(z)
      z = layers.Dropout(0.5)(z)
      oput = layers.Dense(1, activation="sigmoid")(z)
      mdl = keras.Model(inputs=ipt, outputs=oput)

      mdl.compile(loss="binary_crossentropy",
                  optimizer="rmsprop",
                  metrics=["accuracy"])

      _callBacks = [
          keras.callbacks.ModelCheckpoint(
              filepath="feature_extractionPT1.keras",
              save_best_only=True,
              monitor="val_loss")
      ]
      history = mdl.fit(
          train_features, train_labels,
          epochs=15,
          validation_data=(val_features, val_labels),
          callbacks=_callBacks)
```

```
Epoch 1/15
94/94                   4s 22ms/step -
accuracy: 0.9036 - loss: 20.6505 - val_accuracy: 0.9660 - val_loss: 7.1763
Epoch 2/15
94/94                   0s 4ms/step -
accuracy: 0.9772 - loss: 2.6160 - val_accuracy: 0.9820 - val_loss: 3.0761
Epoch 3/15
94/94                   1s 5ms/step -
accuracy: 0.9862 - loss: 1.6699 - val_accuracy: 0.9750 - val_loss: 5.7563
Epoch 4/15
94/94                   1s 5ms/step -
accuracy: 0.9901 - loss: 1.0134 - val_accuracy: 0.9720 - val_loss: 7.3840
Epoch 5/15
94/94                   1s 4ms/step -
accuracy: 0.9934 - loss: 1.2283 - val_accuracy: 0.9740 - val_loss: 6.1850
Epoch 6/15
```

```
94/94              1s 4ms/step -
accuracy: 0.9932 - loss: 0.8453 - val_accuracy: 0.9590 - val_loss: 10.8111
Epoch 7/15
94/94              0s 5ms/step -
accuracy: 0.9941 - loss: 0.9486 - val_accuracy: 0.9780 - val_loss: 6.3744
Epoch 8/15
94/94              0s 5ms/step -
accuracy: 0.9989 - loss: 0.1618 - val_accuracy: 0.9760 - val_loss: 6.0997
Epoch 9/15
94/94              1s 5ms/step -
accuracy: 0.9997 - loss: 0.0265 - val_accuracy: 0.9780 - val_loss: 5.8634
Epoch 10/15
94/94              1s 6ms/step -
accuracy: 0.9999 - loss: 0.0039 - val_accuracy: 0.9730 - val_loss: 6.8180
Epoch 11/15
94/94              0s 4ms/step -
accuracy: 0.9996 - loss: 0.0228 - val_accuracy: 0.9710 - val_loss: 6.5457
Epoch 12/15
94/94              0s 4ms/step -
accuracy: 0.9996 - loss: 0.0518 - val_accuracy: 0.9720 - val_loss: 6.6087
Epoch 13/15
94/94              0s 3ms/step -
accuracy: 0.9956 - loss: 0.3483 - val_accuracy: 0.9730 - val_loss: 6.4729
Epoch 14/15
94/94              0s 3ms/step -
accuracy: 0.9979 - loss: 0.3108 - val_accuracy: 0.9730 - val_loss: 7.6435
Epoch 15/15
94/94              1s 3ms/step -
accuracy: 0.9977 - loss: 0.2591 - val_accuracy: 0.9780 - val_loss: 6.4418
```

accuracy=99.7% val_acc=97.8%

```python
[79]: import matplotlib.pyplot as pl

acc_Value = history.history["accuracy"]
val_acc_Value = history.history["val_accuracy"]
lossVal = history.history["loss"]
val_lossVal = history.history["val_loss"]
epochs = range(1, len(acc_Value) + 1)

pl.plot(epochs, acc_Value, "go", label="Training Accuracy")
pl.plot(epochs, val_acc_Value, "g", label="Validation Accuracy")
pl.title("Model Accuracy Over Epochs")
pl.legend()

pl.figure()
pl.plot(epochs, lossVal, "ro", label="Training Loss")
pl.plot(epochs, val_lossVal, "r", label="Validation Loss")
```
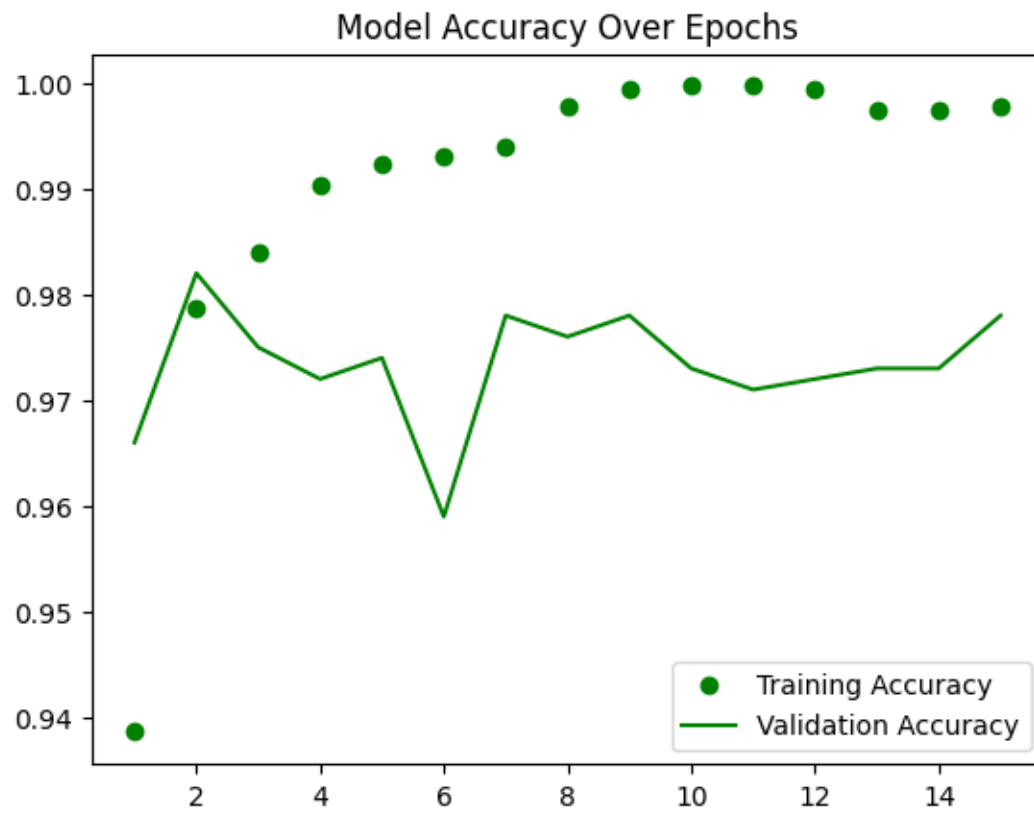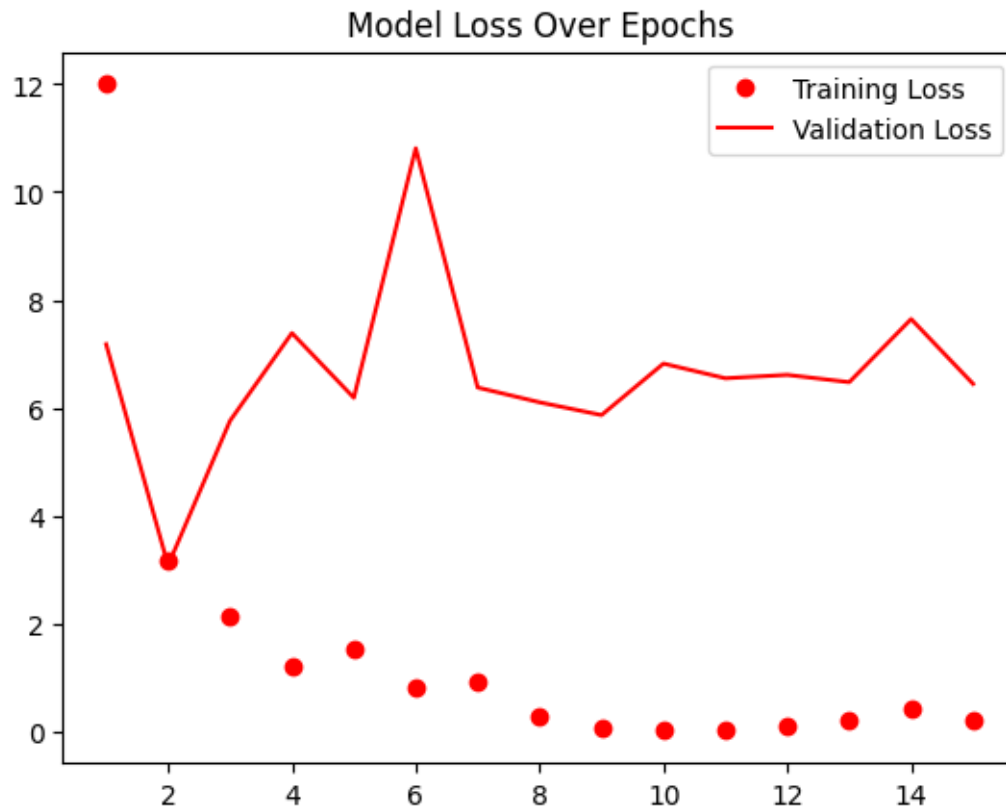
```
pl.title("Model Loss Over Epochs")
pl.legend()

pl.show()
```


Model Accuracy Over Epochs

Model Loss Over Epochs

```
[80]: ba_seConv = keras.applications.vgg16.VGG16(
          weights="imagenet",
          include_top=False
      )
      ba_seConv.trainable = False

      ba_seConv.trainable = True
      print("Number of trainable weights before freezing the convolution base:",␣
        ↪len(ba_seConv.trainable_weights))

      ba_seConv.trainable = False
      print("Number of trainable weights after freezing the convolution base:",␣
        ↪len(ba_seConv.trainable_weights))
```

Number of trainable weights before freezing the convolution base: 26
Number of trainable weights after freezing the convolution base: 0

Feature extraction with Data Augmentation

```
[81]: aug_data = keras.Sequential(
          [
              layers.RandomFlip("horizontal"),
```

```
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ]
)

ipt = keras.Input(shape=(180, 180, 3))
z = aug_data(ipt)
z = keras.applications.vgg16.preprocess_input(z)
z = ba_seConv(z)
z = layers.Flatten()(z)
z = layers.Dense(256)(z)
z = layers.Dropout(0.5)(z)
oput = layers.Dense(1, activation="sigmoid")(z)
mdl = keras.Model(inputs=ipt, outputs=oput)
mdl.compile(loss="binary_crossentropy",
            optimizer="rmsprop",
            metrics=["accuracy"])
```

```
[82]: _callBacks = [
    keras.callbacks.ModelCheckpoint(
        filepath="feature_extraction_with_data_augmentationPT2.keras",
        save_best_only=True,
        monitor="val_loss"
    )
]
hist = mdl.fit(
    train_dataset,
    epochs=5,
    validation_data=validation_dataset,
    callbacks=_callBacks
)
```

```
Epoch 1/5
94/94                28s 253ms/step -
accuracy: 0.8357 - loss: 45.2425 - val_accuracy: 0.9770 - val_loss: 3.1581
Epoch 2/5
94/94                14s 152ms/step -
accuracy: 0.9581 - loss: 5.6371 - val_accuracy: 0.9650 - val_loss: 6.2776
Epoch 3/5
94/94                14s 148ms/step -
accuracy: 0.9471 - loss: 7.5354 - val_accuracy: 0.9680 - val_loss: 5.3251
Epoch 4/5
94/94                21s 154ms/step -
accuracy: 0.9642 - loss: 3.8308 - val_accuracy: 0.9810 - val_loss: 3.1332
Epoch 5/5
94/94                15s 157ms/step -
accuracy: 0.9748 - loss: 2.6789 - val_accuracy: 0.9750 - val_loss: 2.7273
```

```
[83]: mdl_test = keras.models.load_model(
          "feature_extraction_with_data_augmentationPT2.keras"
      )
      lossVal_test, acc_Value_test = mdl_test.evaluate(data_dataset_testing)
      print(f"Test accuracy: {acc_Value_test:.3f}")
```

32/32   **4s** 111ms/step -
accuracy: 0.9608 - loss: 6.5318
Test accuracy: 0.961

Accuracy=96.1% val_Acc=97.4% test_acc=97.5%

Thank You