

Plant_Health_Model

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1 Visual Deep Learning: Plant Health Model

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This notebook describes the creation of a model to evaluate the health of plants. The model was trained with leaves from an apple tree. With this, an application should be able to identify if a tree is unhealthy, by providing a image form a leave of the tree.

The idea to create this model is based on a project that was started last semester. The project GreenThumb is a plant health tracking app, that allows the user to keep track of the health of a plant. With the addition of a trained ai model, the application could be improved a lot in its functionality.

Three models will be implemented and compared with each other.

1.0.2 Applied steps for creating this Machine Learning Modes:

1. Setup
2. Load image data and apply data augmentation
3. Define model
4. Display model structure
5. Training model
6. Write history and plot graphs
7. Evaluate Model
8. Predict with model and display ROC
9. Save trained model
10. Load trained model
11. Test trained model

1.0.3 Experiments:

The notebook tries different experiments for the creation of the best model. As such, steps 3 - 8 are repeated three times with different models.

The results will be discussed shortly at the end of the notebook.

1.0.4 1. Setup

```
[1]: import numpy as np
import tensorflow as tf
from tensorflow.keras import metrics
from sklearn import metrics as skmetrics

from sklearn.metrics import confusion_matrix, accuracy_score

import matplotlib.pyplot as plt
from tensorflow.keras.preprocessing import image
from tensorflow.keras.preprocessing.image import ImageDataGenerator

[2]: #Environment Variables
EPOCHS = 25
BATCH_SIZE = 32
IMG_SIZE = (256, 256)
LEARNING_RATE = 0.001
MODEL_NAME = 'plant_health_model.h5'

#Folder for the data
train_data_dir = './plant_images/train'
valid_data_dir = './plant_images/valid'
test_data_dir = './plant_images/test'

#Different Metrics that get printed in the history
METRICS = [
    metrics.TruePositives(name='tp'),
    metrics.FalsePositives(name='fp'),
    metrics.TrueNegatives(name='tn'),
    metrics.FalseNegatives(name='fn'),
    metrics.CategoricalAccuracy(name='accuracy'),
    metrics.Precision(name='precision'),
    metrics.AUC(name='auc'),
    metrics.MeanAbsoluteError(name='mae'),
    metrics.MeanSquaredError(name='mse')
]
```

1.0.5 2. Load Image Data and apply data augmentation and preprocessing

The structure of the folder is the following:

```
plant_images
├── train
│   ├── Apple_healthy
│   │   ├── image1.png
│   │   └── ...
│   └── Apple_unhealthy
```

```

        image1.png
        ...
    valid
        Apple_healthy
            image1.png
            ...
        Apple_unhealthy
            image1.png
            ...
    test
        Apple_healthy
            image1.png
            ...
        Apple_unhealthy
            image1.png
            ...

```

The train folder includes around 1400 images for the training.

The valid folder includes around 700 images to validate the trained model.

The test folder includes again around 120 images to test the model.

Augmentation: For the augmentation a ImageDataGenerator is used. With this the images for the training and validation are rescaled, sheared, rotated, flipped and zoomed.

The test images are only rescaled.

```

[3]: #Create augmented training data
train_datagen = ImageDataGenerator(rescale=(1. / 255),
                                   shear_range=0.1,
                                   zoom_range=0.1,
                                   rotation_range=10,
                                   horizontal_flip=True,
                                   fill_mode='constant',
                                   validation_split=0.2,
                                   cval=0)

#Create augmented training data
train_dataset = train_datagen.flow_from_directory(train_data_dir,
                                                  target_size=IMG_SIZE,
                                                  batch_size=BATCH_SIZE,
                                                  class_mode='categorical',
                                                  subset='training')

#Create augmented validation data
validation_dataset = train_datagen.flow_from_directory(valid_data_dir,
                                                       target_size=IMG_SIZE,
                                                       batch_size=BATCH_SIZE,

```

```

class_mode='categorical',
subset='validation')

test_datagen = ImageDataGenerator(rescale=(1. / 255))

#Create test data
test_dataset = test_datagen.flow_from_directory(test_data_dir,
                                                target_size=IMG_SIZE,
                                                batch_size=1,
                                                shuffle=False,
                                                class_mode='categorical')

```

Found 1458 images belonging to 2 classes.
Found 126 images belonging to 2 classes.
Found 714 images belonging to 2 classes.

```

[4]: # Checks if classes where found and displays them
num_classes = train_dataset.num_classes
class_names = list(train_dataset.class_indices.keys())
print(class_names)

```

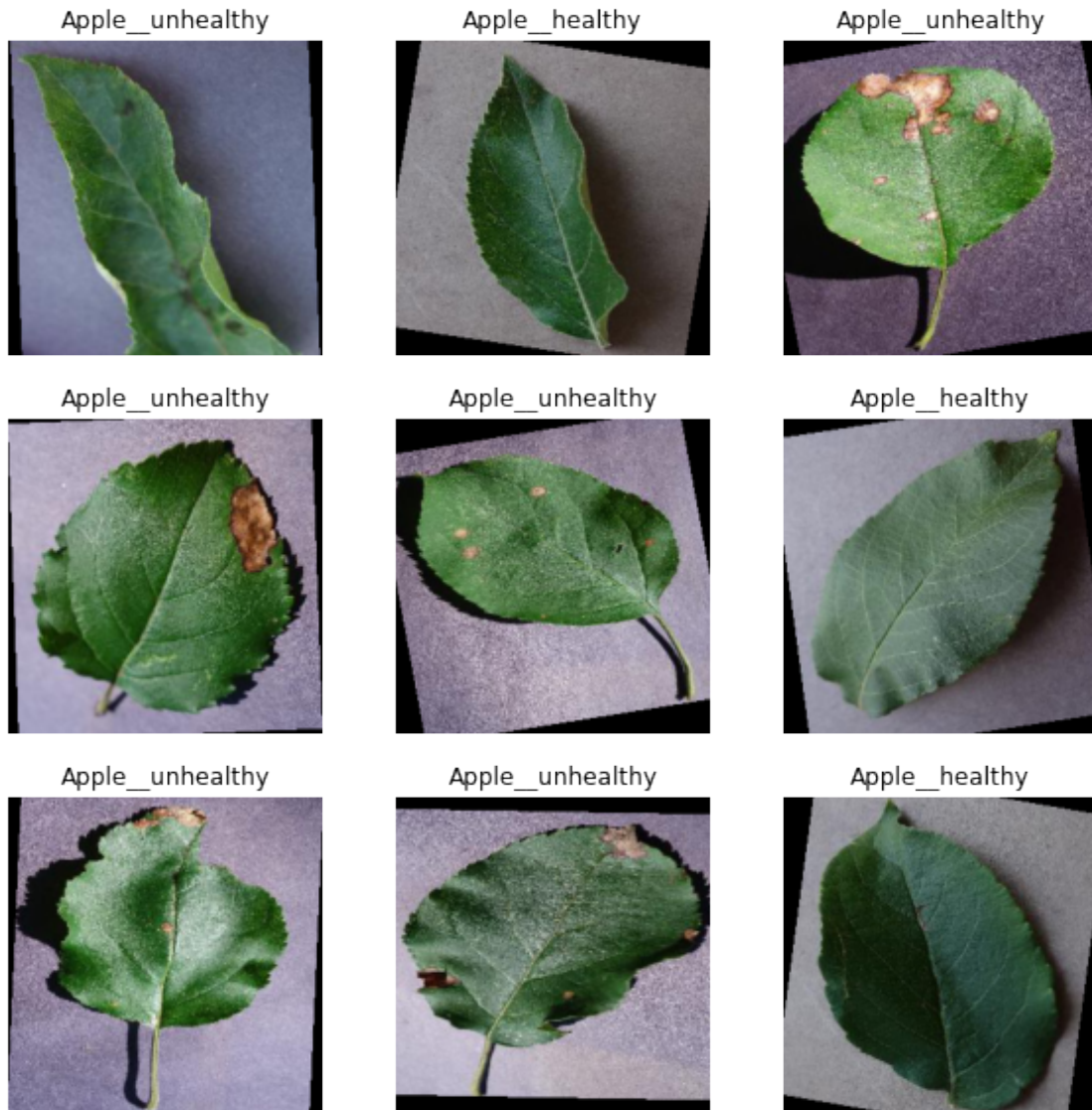
['Apple__healthy', 'Apple__unhealthy']

1.0.6 Display augmented image data

```

[5]: # display the random validation data for testing
x,y = validation_dataset.next()
labels = list(np.argmax(l) for l in y)
plt.figure(figsize=(10, 10))
for i in range(9):
    ax = plt.subplot(3, 3, i + 1)
    plt.imshow(x[i])
    plt.title(class_names[labels[i]])
    plt.axis("off")

```



1.1 The experiments with different models start here

1.1.1 3. Create and compile model 1

This model uses two hidden convolution layers and one dense layer to analyse the images. In between the hidden layers, max-pooling manipulates the values, to create a better learning base. Based on literature the best hidden layer activation is the relu function and for the dense activation softmax. For the loss function, the categorical_crossentropy or the binary_crossentropy (since there are only two classes) was possible for image recognition. For this example, categorical_crossentropy worked better. Finally, this model also normalizes the output of the hidden input layer. Thus, reducing covariate shift.

```
[6]: model1 = tf.keras.models.Sequential([
    tf.keras.layers.Conv2D(128, (3, 3), input_shape=(IMG_SIZE[0], IMG_SIZE[1], 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Conv2D(128, (3, 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])
```

```
[7]: opt = tf.keras.optimizers.Adam(lr=LEARNING_RATE)
model1.compile(optimizer=opt,
    loss='categorical_crossentropy',
    metrics=METRICS)
```

1.1.2 4. Display model structure 1

```
[8]: model1.summary()
```

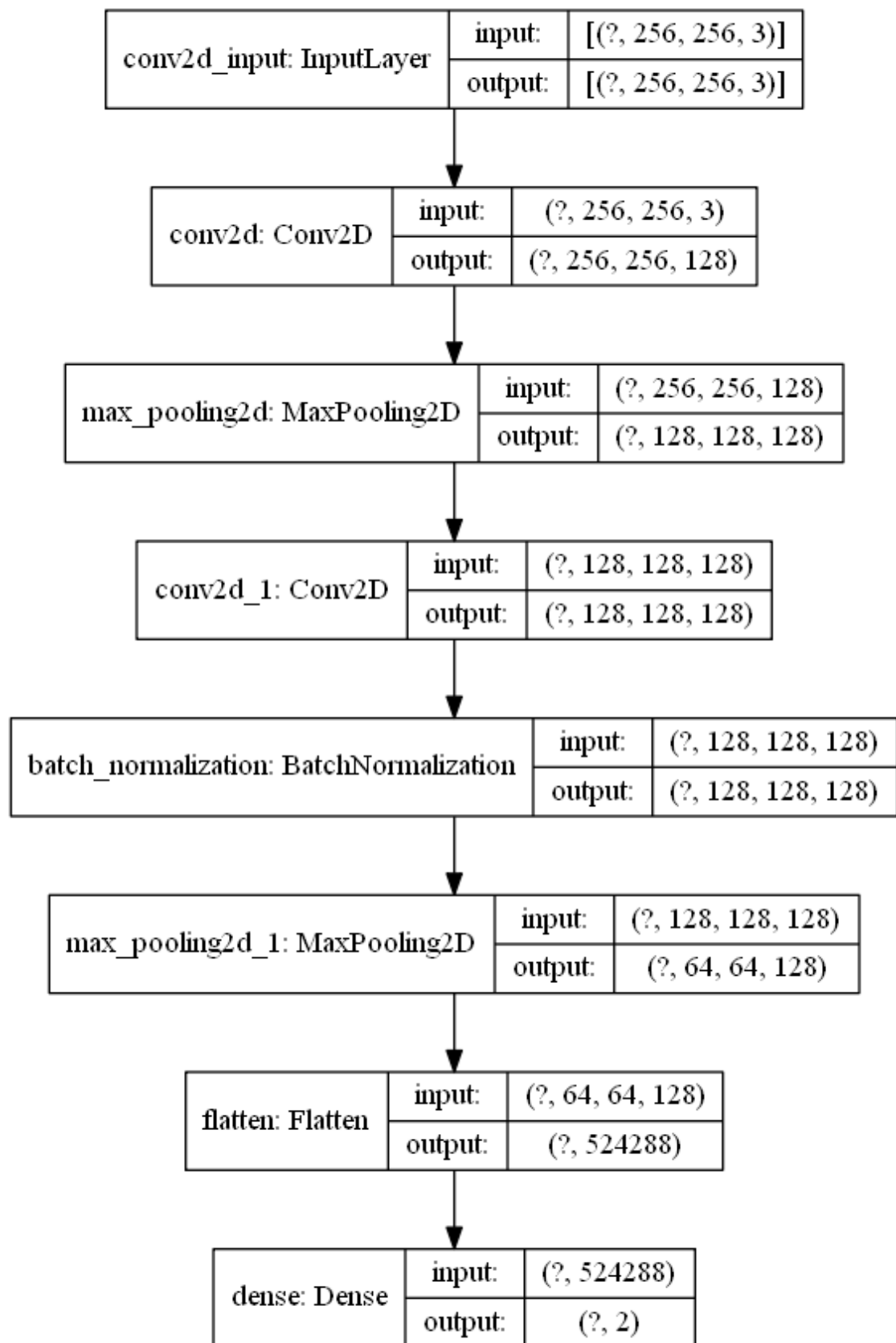
Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 256, 256, 128)	3456
max_pooling2d (MaxPooling2D)	(None, 128, 128, 128)	0
conv2d_1 (Conv2D)	(None, 128, 128, 128)	147456
batch_normalization (Batch Normalization)	(None, 128, 128, 128)	512
max_pooling2d_1 (MaxPooling2D)	(None, 64, 64, 128)	0
flatten (Flatten)	(None, 524288)	0
dense (Dense)	(None, 2)	1048578

Total params: 1,200,002
 Trainable params: 1,199,746
 Non-trainable params: 256

```
[9]: tf.keras.utils.plot_model(model1, show_shapes=True)
```

```
[9]:
```



1.1.3 5. Training model 1

```
[10]: def train_model(model, model_name):  
    filepath = './models/' + model_name + '.hdf5'  
    checkpoint = tf.keras.callbacks.ModelCheckpoint(filepath,   
    ↪monitor='val_accuracy', verbose=1,   
    ↪mode='max')  
    save_best_only=True,   
    callbacks_list = [checkpoint]  
  
    history = model.fit(train_dataset,   
                        epochs=EPOCHS,   
                        validation_data=validation_dataset,   
                        callbacks=callbacks_list)  
  
    return history  
  
history1 = train_model(model1, "Model_1")
```

Epoch 1/25

46/46 [=====] - ETA: 0s - loss: 2.6319 - tp: 1152.0000
- fp: 306.0000 - tn: 1152.0000 - fn: 306.0000 - accuracy: 0.7901 - precision:
0.7901 - auc: 0.8367 - mae: 0.2089 - mse: 0.1891

Epoch 00001: val_accuracy improved from -inf to 0.80159, saving model to
./models\Model_1.hdf5

46/46 [=====] - 16s 357ms/step - loss: 2.6319 - tp:
1152.0000 - fp: 306.0000 - tn: 1152.0000 - fn: 306.0000 - accuracy: 0.7901 -
precision: 0.7901 - auc: 0.8367 - mae: 0.2089 - mse: 0.1891 - val_loss: 0.3799 -
val_tp: 101.0000 - val_fp: 25.0000 - val_tn: 101.0000 - val_fn: 25.0000 -
val_accuracy: 0.8016 - val_precision: 0.8016 - val_auc: 0.9191 - val_mae: 0.2761
- val_mse: 0.1197

Epoch 2/25

46/46 [=====] - ETA: 0s - loss: 0.6925 - tp: 1268.0000
- fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 - precision:
0.8697 - auc: 0.9241 - mae: 0.1335 - mse: 0.1084

Epoch 00002: val_accuracy did not improve from 0.80159

46/46 [=====] - 15s 336ms/step - loss: 0.6925 - tp:
1268.0000 - fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 -
precision: 0.8697 - auc: 0.9241 - mae: 0.1335 - mse: 0.1084 - val_loss: 0.5499 -
val_tp: 88.0000 - val_fp: 38.0000 - val_tn: 88.0000 - val_fn: 38.0000 -
val_accuracy: 0.6984 - val_precision: 0.6984 - val_auc: 0.8018 - val_mae: 0.4025
- val_mse: 0.1855

Epoch 3/25

46/46 [=====] - ETA: 0s - loss: 0.6643 - tp: 1204.0000
- fp: 254.0000 - tn: 1204.0000 - fn: 254.0000 - accuracy: 0.8258 - precision:
0.8258 - auc: 0.8986 - mae: 0.1851 - mse: 0.1360

Epoch 00003: val_accuracy did not improve from 0.80159
46/46 [=====] - 15s 336ms/step - loss: 0.6643 - tp: 1204.0000 - fp: 254.0000 - tn: 1204.0000 - fn: 254.0000 - accuracy: 0.8258 - precision: 0.8258 - auc: 0.8986 - mae: 0.1851 - mse: 0.1360 - val_loss: 0.6416 - val_tp: 70.0000 - val_fp: 56.0000 - val_tn: 70.0000 - val_fn: 56.0000 - val_accuracy: 0.5556 - val_precision: 0.5556 - val_auc: 0.7476 - val_mae: 0.4314 - val_mse: 0.2282

Epoch 4/25
46/46 [=====] - ETA: 0s - loss: 0.4480 - tp: 1227.0000 - fp: 231.0000 - tn: 1227.0000 - fn: 231.0000 - accuracy: 0.8416 - precision: 0.8416 - auc: 0.9150 - mae: 0.1842 - mse: 0.1205

Epoch 00004: val_accuracy did not improve from 0.80159
46/46 [=====] - 15s 336ms/step - loss: 0.4480 - tp: 1227.0000 - fp: 231.0000 - tn: 1227.0000 - fn: 231.0000 - accuracy: 0.8416 - precision: 0.8416 - auc: 0.9150 - mae: 0.1842 - mse: 0.1205 - val_loss: 0.7952 - val_tp: 61.0000 - val_fp: 65.0000 - val_tn: 61.0000 - val_fn: 65.0000 - val_accuracy: 0.4841 - val_precision: 0.4841 - val_auc: 0.7218 - val_mae: 0.4396 - val_mse: 0.3027

Epoch 5/25
46/46 [=====] - ETA: 0s - loss: 0.3338 - tp: 1278.0000 - fp: 180.0000 - tn: 1278.0000 - fn: 180.0000 - accuracy: 0.8765 - precision: 0.8765 - auc: 0.9415 - mae: 0.1635 - mse: 0.0933

Epoch 00005: val_accuracy did not improve from 0.80159
46/46 [=====] - 16s 340ms/step - loss: 0.3338 - tp: 1278.0000 - fp: 180.0000 - tn: 1278.0000 - fn: 180.0000 - accuracy: 0.8765 - precision: 0.8765 - auc: 0.9415 - mae: 0.1635 - mse: 0.0933 - val_loss: 0.6743 - val_tp: 63.0000 - val_fp: 63.0000 - val_tn: 63.0000 - val_fn: 63.0000 - val_accuracy: 0.5000 - val_precision: 0.5000 - val_auc: 0.7157 - val_mae: 0.4185 - val_mse: 0.2516

Epoch 6/25
46/46 [=====] - ETA: 0s - loss: 0.2555 - tp: 1321.0000 - fp: 137.0000 - tn: 1321.0000 - fn: 137.0000 - accuracy: 0.9060 - precision: 0.9060 - auc: 0.9630 - mae: 0.1353 - mse: 0.0735

Epoch 00006: val_accuracy did not improve from 0.80159
46/46 [=====] - 15s 336ms/step - loss: 0.2555 - tp: 1321.0000 - fp: 137.0000 - tn: 1321.0000 - fn: 137.0000 - accuracy: 0.9060 - precision: 0.9060 - auc: 0.9630 - mae: 0.1353 - mse: 0.0735 - val_loss: 0.9736 - val_tp: 61.0000 - val_fp: 65.0000 - val_tn: 61.0000 - val_fn: 65.0000 - val_accuracy: 0.4841 - val_precision: 0.4841 - val_auc: 0.7149 - val_mae: 0.4614 - val_mse: 0.3614

Epoch 7/25
46/46 [=====] - ETA: 0s - loss: 0.2424 - tp: 1312.0000 - fp: 146.0000 - tn: 1312.0000 - fn: 146.0000 - accuracy: 0.8999 - precision: 0.8999 - auc: 0.9655 - mae: 0.1273 - mse: 0.0729

Epoch 00007: val_accuracy improved from 0.80159 to 0.84127, saving model to ./models\Model_1.hdf5
46/46 [=====] - 15s 336ms/step - loss: 0.2424 - tp: 1312.0000 - fp: 146.0000 - tn: 1312.0000 - fn: 146.0000 - accuracy: 0.8999 -

precision: 0.8999 - auc: 0.9655 - mae: 0.1273 - mse: 0.0729 - val_loss: 0.4171 -
val_tp: 106.0000 - val_fp: 20.0000 - val_tn: 106.0000 - val_fn: 20.0000 -
val_accuracy: 0.8413 - val_precision: 0.8413 - val_auc: 0.9302 - val_mae: 0.3158
- val_mse: 0.1303

Epoch 8/25

46/46 [=====] - ETA: 0s - loss: 0.2430 - tp: 1320.0000
- fp: 138.0000 - tn: 1320.0000 - fn: 138.0000 - accuracy: 0.9053 - precision:
0.9053 - auc: 0.9655 - mae: 0.1266 - mse: 0.0709

Epoch 00008: val_accuracy did not improve from 0.84127

46/46 [=====] - 15s 336ms/step - loss: 0.2430 - tp:
1320.0000 - fp: 138.0000 - tn: 1320.0000 - fn: 138.0000 - accuracy: 0.9053 -
precision: 0.9053 - auc: 0.9655 - mae: 0.1266 - mse: 0.0709 - val_loss: 0.4184 -
val_tp: 101.0000 - val_fp: 25.0000 - val_tn: 101.0000 - val_fn: 25.0000 -
val_accuracy: 0.8016 - val_precision: 0.8016 - val_auc: 0.8941 - val_mae: 0.3012
- val_mse: 0.1369

Epoch 9/25

46/46 [=====] - ETA: 0s - loss: 0.2162 - tp: 1343.0000
- fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 - precision:
0.9211 - auc: 0.9727 - mae: 0.1140 - mse: 0.0633

Epoch 00009: val_accuracy improved from 0.84127 to 0.90476, saving model to
./models\Model_1.hdf5

46/46 [=====] - 16s 343ms/step - loss: 0.2162 - tp:
1343.0000 - fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 -
precision: 0.9211 - auc: 0.9727 - mae: 0.1140 - mse: 0.0633 - val_loss: 0.3255 -
val_tp: 114.0000 - val_fp: 12.0000 - val_tn: 114.0000 - val_fn: 12.0000 -
val_accuracy: 0.9048 - val_precision: 0.9048 - val_auc: 0.9484 - val_mae: 0.2120
- val_mse: 0.0906

Epoch 10/25

46/46 [=====] - ETA: 0s - loss: 0.2368 - tp: 1333.0000
- fp: 125.0000 - tn: 1333.0000 - fn: 125.0000 - accuracy: 0.9143 - precision:
0.9143 - auc: 0.9691 - mae: 0.1158 - mse: 0.0661

Epoch 00010: val_accuracy improved from 0.90476 to 0.92857, saving model to
./models\Model_1.hdf5

46/46 [=====] - 17s 372ms/step - loss: 0.2368 - tp:
1333.0000 - fp: 125.0000 - tn: 1333.0000 - fn: 125.0000 - accuracy: 0.9143 -
precision: 0.9143 - auc: 0.9691 - mae: 0.1158 - mse: 0.0661 - val_loss: 0.2273 -
val_tp: 117.0000 - val_fp: 9.0000 - val_tn: 117.0000 - val_fn: 9.0000 -
val_accuracy: 0.9286 - val_precision: 0.9286 - val_auc: 0.9858 - val_mae: 0.1805
- val_mse: 0.0610

Epoch 11/25

46/46 [=====] - ETA: 0s - loss: 0.2657 - tp: 1304.0000
- fp: 154.0000 - tn: 1304.0000 - fn: 154.0000 - accuracy: 0.8944 - precision:
0.8944 - auc: 0.9595 - mae: 0.1330 - mse: 0.0744

Epoch 00011: val_accuracy did not improve from 0.92857

46/46 [=====] - 16s 352ms/step - loss: 0.2657 - tp:
1304.0000 - fp: 154.0000 - tn: 1304.0000 - fn: 154.0000 - accuracy: 0.8944 -
precision: 0.8944 - auc: 0.9595 - mae: 0.1330 - mse: 0.0744 - val_loss: 0.2356 -
val_tp: 115.0000 - val_fp: 11.0000 - val_tn: 115.0000 - val_fn: 11.0000 -

val_accuracy: 0.9127 - val_precision: 0.9127 - val_auc: 0.9735 - val_mae: 0.1732
- val_mse: 0.0668
Epoch 12/25
46/46 [=====] - ETA: 0s - loss: 0.2521 - tp: 1330.0000
- fp: 128.0000 - tn: 1330.0000 - fn: 128.0000 - accuracy: 0.9122 - precision:
0.9122 - auc: 0.9660 - mae: 0.1138 - mse: 0.0680
Epoch 00012: val_accuracy improved from 0.92857 to 0.94444, saving model to
./models\Model_1.hdf5
46/46 [=====] - 16s 343ms/step - loss: 0.2521 - tp:
1330.0000 - fp: 128.0000 - tn: 1330.0000 - fn: 128.0000 - accuracy: 0.9122 -
precision: 0.9122 - auc: 0.9660 - mae: 0.1138 - mse: 0.0680 - val_loss: 0.2058 -
val_tp: 119.0000 - val_fp: 7.0000 - val_tn: 119.0000 - val_fn: 7.0000 -
val_accuracy: 0.9444 - val_precision: 0.9444 - val_auc: 0.9742 - val_mae: 0.1297
- val_mse: 0.0510
Epoch 13/25
46/46 [=====] - ETA: 0s - loss: 0.2797 - tp: 1312.0000
- fp: 146.0000 - tn: 1312.0000 - fn: 146.0000 - accuracy: 0.8999 - precision:
0.8999 - auc: 0.9629 - mae: 0.1154 - mse: 0.0737
Epoch 00013: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 348ms/step - loss: 0.2797 - tp:
1312.0000 - fp: 146.0000 - tn: 1312.0000 - fn: 146.0000 - accuracy: 0.8999 -
precision: 0.8999 - auc: 0.9629 - mae: 0.1154 - mse: 0.0737 - val_loss: 0.3343 -
val_tp: 104.0000 - val_fp: 22.0000 - val_tn: 104.0000 - val_fn: 22.0000 -
val_accuracy: 0.8254 - val_precision: 0.8254 - val_auc: 0.9297 - val_mae: 0.2116
- val_mse: 0.1092
Epoch 14/25
46/46 [=====] - ETA: 0s - loss: 0.3291 - tp: 1283.0000
- fp: 175.0000 - tn: 1283.0000 - fn: 175.0000 - accuracy: 0.8800 - precision:
0.8800 - auc: 0.9509 - mae: 0.1395 - mse: 0.0901
Epoch 00014: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 343ms/step - loss: 0.3291 - tp:
1283.0000 - fp: 175.0000 - tn: 1283.0000 - fn: 175.0000 - accuracy: 0.8800 -
precision: 0.8800 - auc: 0.9509 - mae: 0.1395 - mse: 0.0901 - val_loss: 0.8696 -
val_tp: 92.0000 - val_fp: 34.0000 - val_tn: 92.0000 - val_fn: 34.0000 -
val_accuracy: 0.7302 - val_precision: 0.7302 - val_auc: 0.8568 - val_mae: 0.2618
- val_mse: 0.2231
Epoch 15/25
46/46 [=====] - ETA: 0s - loss: 0.2679 - tp: 1317.0000
- fp: 141.0000 - tn: 1317.0000 - fn: 141.0000 - accuracy: 0.9033 - precision:
0.9033 - auc: 0.9609 - mae: 0.1295 - mse: 0.0772
Epoch 00015: val_accuracy did not improve from 0.94444
46/46 [=====] - 17s 361ms/step - loss: 0.2679 - tp:
1317.0000 - fp: 141.0000 - tn: 1317.0000 - fn: 141.0000 - accuracy: 0.9033 -
precision: 0.9033 - auc: 0.9609 - mae: 0.1295 - mse: 0.0772 - val_loss: 0.3128 -
val_tp: 107.0000 - val_fp: 19.0000 - val_tn: 107.0000 - val_fn: 19.0000 -
val_accuracy: 0.8492 - val_precision: 0.8492 - val_auc: 0.9482 - val_mae: 0.1660
- val_mse: 0.1020
Epoch 16/25

46/46 [=====] - ETA: 0s - loss: 0.2074 - tp: 1344.0000
- fp: 114.0000 - tn: 1344.0000 - fn: 114.0000 - accuracy: 0.9218 - precision:
0.9218 - auc: 0.9731 - mae: 0.1163 - mse: 0.0606
Epoch 00016: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 358ms/step - loss: 0.2074 - tp:
1344.0000 - fp: 114.0000 - tn: 1344.0000 - fn: 114.0000 - accuracy: 0.9218 -
precision: 0.9218 - auc: 0.9731 - mae: 0.1163 - mse: 0.0606 - val_loss: 0.5912 -
val_tp: 97.0000 - val_fp: 29.0000 - val_tn: 97.0000 - val_fn: 29.0000 -
val_accuracy: 0.7698 - val_precision: 0.7698 - val_auc: 0.8939 - val_mae: 0.2137
- val_mse: 0.1647
Epoch 17/25
46/46 [=====] - ETA: 0s - loss: 0.2186 - tp: 1321.0000
- fp: 137.0000 - tn: 1321.0000 - fn: 137.0000 - accuracy: 0.9060 - precision:
0.9060 - auc: 0.9713 - mae: 0.1236 - mse: 0.0669
Epoch 00017: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 348ms/step - loss: 0.2186 - tp:
1321.0000 - fp: 137.0000 - tn: 1321.0000 - fn: 137.0000 - accuracy: 0.9060 -
precision: 0.9060 - auc: 0.9713 - mae: 0.1236 - mse: 0.0669 - val_loss: 0.2309 -
val_tp: 117.0000 - val_fp: 9.0000 - val_tn: 117.0000 - val_fn: 9.0000 -
val_accuracy: 0.9286 - val_precision: 0.9286 - val_auc: 0.9718 - val_mae: 0.1053
- val_mse: 0.0537
Epoch 18/25
46/46 [=====] - ETA: 0s - loss: 0.2060 - tp: 1342.0000
- fp: 116.0000 - tn: 1342.0000 - fn: 116.0000 - accuracy: 0.9204 - precision:
0.9204 - auc: 0.9741 - mae: 0.1079 - mse: 0.0587
Epoch 00018: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 340ms/step - loss: 0.2060 - tp:
1342.0000 - fp: 116.0000 - tn: 1342.0000 - fn: 116.0000 - accuracy: 0.9204 -
precision: 0.9204 - auc: 0.9741 - mae: 0.1079 - mse: 0.0587 - val_loss: 0.9228 -
val_tp: 97.0000 - val_fp: 29.0000 - val_tn: 97.0000 - val_fn: 29.0000 -
val_accuracy: 0.7698 - val_precision: 0.7698 - val_auc: 0.8449 - val_mae: 0.2387
- val_mse: 0.2052
Epoch 19/25
46/46 [=====] - ETA: 0s - loss: 0.2696 - tp: 1318.0000
- fp: 140.0000 - tn: 1318.0000 - fn: 140.0000 - accuracy: 0.9040 - precision:
0.9040 - auc: 0.9598 - mae: 0.1270 - mse: 0.0746
Epoch 00019: val_accuracy did not improve from 0.94444
46/46 [=====] - 16s 339ms/step - loss: 0.2696 - tp:
1318.0000 - fp: 140.0000 - tn: 1318.0000 - fn: 140.0000 - accuracy: 0.9040 -
precision: 0.9040 - auc: 0.9598 - mae: 0.1270 - mse: 0.0746 - val_loss: 0.1908 -
val_tp: 116.0000 - val_fp: 10.0000 - val_tn: 116.0000 - val_fn: 10.0000 -
val_accuracy: 0.9206 - val_precision: 0.9206 - val_auc: 0.9770 - val_mae: 0.1061
- val_mse: 0.0579
Epoch 20/25
46/46 [=====] - ETA: 0s - loss: 0.2363 - tp: 1325.0000
- fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 - precision:
0.9088 - auc: 0.9679 - mae: 0.1245 - mse: 0.0672
Epoch 00020: val_accuracy did not improve from 0.94444

46/46 [=====] - 16s 340ms/step - loss: 0.2363 - tp: 1325.0000 - fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 - precision: 0.9088 - auc: 0.9679 - mae: 0.1245 - mse: 0.0672 - val_loss: 0.3816 - val_tp: 114.0000 - val_fp: 12.0000 - val_tn: 114.0000 - val_fn: 12.0000 - val_accuracy: 0.9048 - val_precision: 0.9048 - val_auc: 0.9547 - val_mae: 0.1139 - val_mse: 0.0742

Epoch 21/25

46/46 [=====] - ETA: 0s - loss: 0.2539 - tp: 1326.0000 - fp: 132.0000 - tn: 1326.0000 - fn: 132.0000 - accuracy: 0.9095 - precision: 0.9095 - auc: 0.9633 - mae: 0.1209 - mse: 0.0696

Epoch 00021: val_accuracy did not improve from 0.94444

46/46 [=====] - 16s 339ms/step - loss: 0.2539 - tp: 1326.0000 - fp: 132.0000 - tn: 1326.0000 - fn: 132.0000 - accuracy: 0.9095 - precision: 0.9095 - auc: 0.9633 - mae: 0.1209 - mse: 0.0696 - val_loss: 0.2727 - val_tp: 112.0000 - val_fp: 14.0000 - val_tn: 112.0000 - val_fn: 14.0000 - val_accuracy: 0.8889 - val_precision: 0.8889 - val_auc: 0.9666 - val_mae: 0.1160 - val_mse: 0.0815

Epoch 22/25

46/46 [=====] - ETA: 0s - loss: 0.2555 - tp: 1329.0000 - fp: 129.0000 - tn: 1329.0000 - fn: 129.0000 - accuracy: 0.9115 - precision: 0.9115 - auc: 0.9654 - mae: 0.1141 - mse: 0.0676

Epoch 00022: val_accuracy did not improve from 0.94444

46/46 [=====] - 16s 338ms/step - loss: 0.2555 - tp: 1329.0000 - fp: 129.0000 - tn: 1329.0000 - fn: 129.0000 - accuracy: 0.9115 - precision: 0.9115 - auc: 0.9654 - mae: 0.1141 - mse: 0.0676 - val_loss: 0.2927 - val_tp: 111.0000 - val_fp: 15.0000 - val_tn: 111.0000 - val_fn: 15.0000 - val_accuracy: 0.8810 - val_precision: 0.8810 - val_auc: 0.9498 - val_mae: 0.1602 - val_mse: 0.0889

Epoch 23/25

46/46 [=====] - ETA: 0s - loss: 0.2330 - tp: 1334.0000 - fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 - precision: 0.9150 - auc: 0.9680 - mae: 0.1215 - mse: 0.0653

Epoch 00023: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 336ms/step - loss: 0.2330 - tp: 1334.0000 - fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 - precision: 0.9150 - auc: 0.9680 - mae: 0.1215 - mse: 0.0653 - val_loss: 0.1890 - val_tp: 119.0000 - val_fp: 7.0000 - val_tn: 119.0000 - val_fn: 7.0000 - val_accuracy: 0.9444 - val_precision: 0.9444 - val_auc: 0.9801 - val_mae: 0.0721 - val_mse: 0.0449

Epoch 24/25

46/46 [=====] - ETA: 0s - loss: 0.2197 - tp: 1342.0000 - fp: 116.0000 - tn: 1342.0000 - fn: 116.0000 - accuracy: 0.9204 - precision: 0.9204 - auc: 0.9711 - mae: 0.1155 - mse: 0.0637

Epoch 00024: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 336ms/step - loss: 0.2197 - tp: 1342.0000 - fp: 116.0000 - tn: 1342.0000 - fn: 116.0000 - accuracy: 0.9204 - precision: 0.9204 - auc: 0.9711 - mae: 0.1155 - mse: 0.0637 - val_loss: 0.4228 - val_tp: 114.0000 - val_fp: 12.0000 - val_tn: 114.0000 - val_fn: 12.0000 -

```

val_accuracy: 0.9048 - val_precision: 0.9048 - val_auc: 0.9427 - val_mae: 0.1371
- val_mse: 0.0900
Epoch 25/25
46/46 [=====] - ETA: 0s - loss: 0.2386 - tp: 1325.0000
- fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 - precision:
0.9088 - auc: 0.9684 - mae: 0.1147 - mse: 0.0674
Epoch 00025: val_accuracy did not improve from 0.94444
46/46 [=====] - 15s 337ms/step - loss: 0.2386 - tp:
1325.0000 - fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 -
precision: 0.9088 - auc: 0.9684 - mae: 0.1147 - mse: 0.0674 - val_loss: 0.1953 -
val_tp: 117.0000 - val_fp: 9.0000 - val_tn: 117.0000 - val_fn: 9.0000 -
val_accuracy: 0.9286 - val_precision: 0.9286 - val_auc: 0.9746 - val_mae: 0.0930
- val_mse: 0.0571

```

1.1.4 6. Write history and plot graphs 1

```

[11]: def print_history(history):
    acc = history.history['accuracy']
    val_acc = history.history['val_accuracy']

    loss = history.history['loss']
    val_loss = history.history['val_loss']

    auc = history.history['auc']
    val_auc = history.history['val_auc']

    plt.figure(figsize=(8, 8))
    plt.subplot(2, 1, 1)
    plt.plot(acc, label='Training Accuracy')
    plt.plot(val_acc, label='Validation Accuracy')
    plt.legend(loc='lower right')
    plt.ylabel('Accuracy')
    plt.ylim([min(plt.ylim()), 1])
    plt.title('Training and Validation Accuracy')

    plt.figure(figsize=(8, 8))
    plt.subplot(2, 1, 2)
    plt.plot(loss, label='Training Loss')
    plt.plot(val_loss, label='Validation Loss')
    plt.legend(loc='upper right')
    plt.ylabel('Cross Entropy')
    plt.ylim([0, 1.0])
    plt.title('Training and Validation Loss')
    plt.xlabel('epoch')
    plt.show()

    plt.figure(figsize=(8, 8))

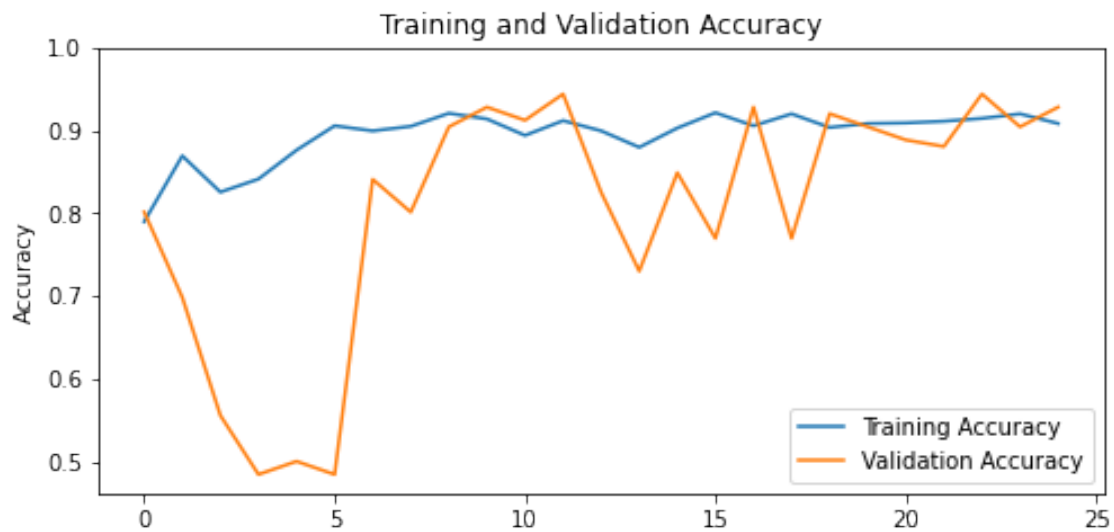
```

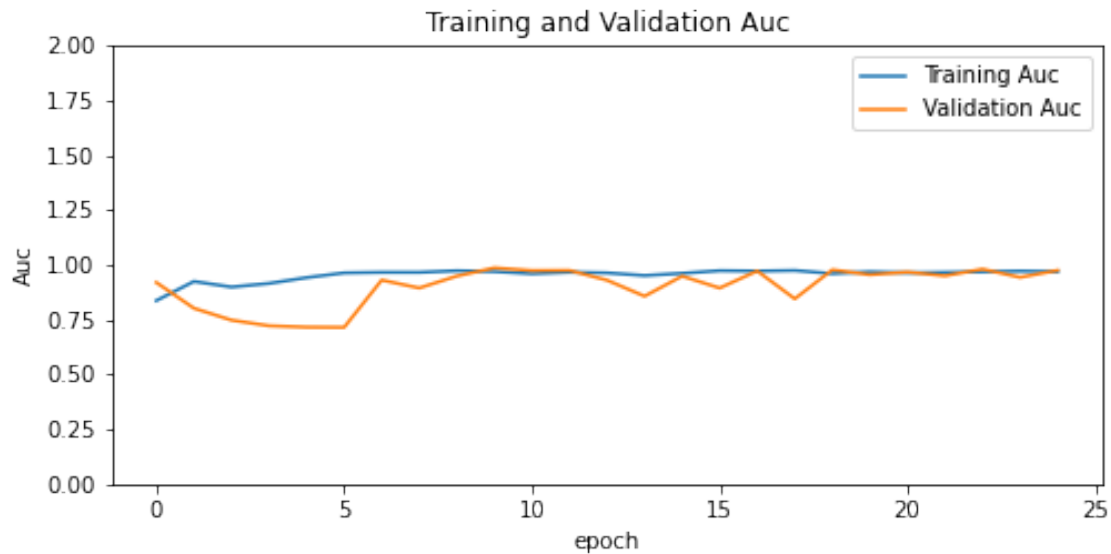
```

plt.subplot(2, 1, 1)
plt.plot(auc, label='Training Auc')
plt.plot(val_auc, label='Validation Auc')
plt.legend(loc='upper right')
plt.ylabel('Auc')
plt.ylim([0,2.0])
plt.title('Training and Validation Auc')
plt.xlabel('epoch')
plt.show()

print_history(history1)

```





1.1.5 7. Evaluate the model 1

```
[12]: def print_model_evaluation(model):
    result = model.evaluate(test_dataset)
    metrics = ["loss", "tp", "fp", "tn", "fn", "accuracy", "precision", "auc", "mae", "mse"]
    for i in range(len(result)):
        print("{} : {}".format(metrics[i], round(result[i], 3)))

print_model_evaluation(model1);
```

```
714/714 [=====] - 3s 4ms/step - loss: 0.4899 - tp:
607.0000 - fp: 107.0000 - tn: 607.0000 - fn: 107.0000 - accuracy: 0.8501 -
precision: 0.8501 - auc: 0.9362 - mae: 0.1512 - mse: 0.1226
loss : 0.49
tp : 607.0
fp : 107.0
tn : 607.0
fn : 107.0
accuracy : 0.85
precision : 0.85
auc : 0.936
mae : 0.151
mse : 0.123
```


1.1.6 8. Predict with model 1

```
[13]: #prediction does not predict all images but only a part amount
def predict_and_print_roc(model):
    #Retrieve one batch of images from the test set
    train_dataset.reset()

    image_batch = []
    label_batch = []
    max_iter = 5 # maximum number of iterations, in each iteration one batch is
    →generated;
    i = 0
    for d, l in train_dataset:
        image_batch.append(d)
        label_batch.append(l)
        i += 1
        if i == max_iter:
            break

    image_batch = np.array(image_batch)
    image_batch = np.reshape(image_batch, (image_batch.shape[0] * image_batch.
    →shape[1], ) + image_batch.shape[2: ])

    label_batch = np.array(label_batch)
    label_batch = np.reshape(label_batch, (label_batch.shape[0] * label_batch.
    →shape[1], ) + label_batch.shape[2: ])

    # Predict the images from the batch
    predictions = model.predict(image_batch)

    # Visualise the actual value and the prediction in numerical form
    probs = list(np.argmax(x) for x in predictions)
    labels = list(np.argmax(x) for x in label_batch)
    print('Label Predictions:\n', probs)
    print('Real Labels:\n', labels)

    confusion = confusion_matrix(labels, probs)
    print('\nConfusion Matrix:')
    print(confusion)

    print('\nAccuracy: {:.2f}\n'.format(accuracy_score(labels, probs)))

    #Print the first 9 Images from the batch and the estimated prediction.
    plt.figure(figsize=(10, 10))
    for i in range(9):
        ax = plt.subplot(3, 3, i + 1)
```

```

plt.imshow(image_batch[i])
plt.title(class_names[probs[i]])
plt.axis("off")

#Calculate the roc curve
fpr, tpr, _ = skmetrics.roc_curve(label_batch.ravel(), predictions.ravel())
roc_auc = skmetrics.auc(fpr, tpr)

#Display ROC curve and the AUC
plt.figure(figsize=(5, 5))
plt.title('ROC')
plt.plot(fpr, tpr, 'b', label = 'AUC = %0.2f' % roc_auc)
plt.legend(loc = 'lower right')
plt.plot([0, 1], [0, 1], 'r--')
plt.xlim([0, 1])
plt.ylim([0, 1])
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()

predict_and_print_roc(model1);

```

Label Predictions:

```

[0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1,
0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0,
1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 1, 0, 0, 0,
1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0,
0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1,
1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 0, 0, 0, 1, 1, 0, 1, 1]

```

Real Labels:

```

[0, 1, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 0, 1, 1,
0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0,
1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0,
1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0,
0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1,
1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 1, 0, 1, 1]

```

Confusion Matrix:

```

[[81  0]
 [15 64]]

```

Accuracy: 0.91

Apple__healthy



Apple__healthy



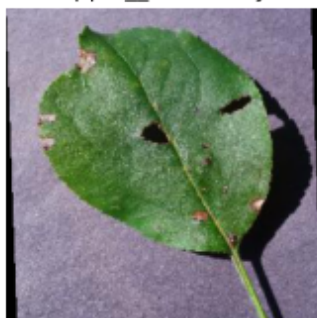
Apple__healthy



Apple__healthy



Apple_unhealthy



Apple__healthy



Apple_unhealthy

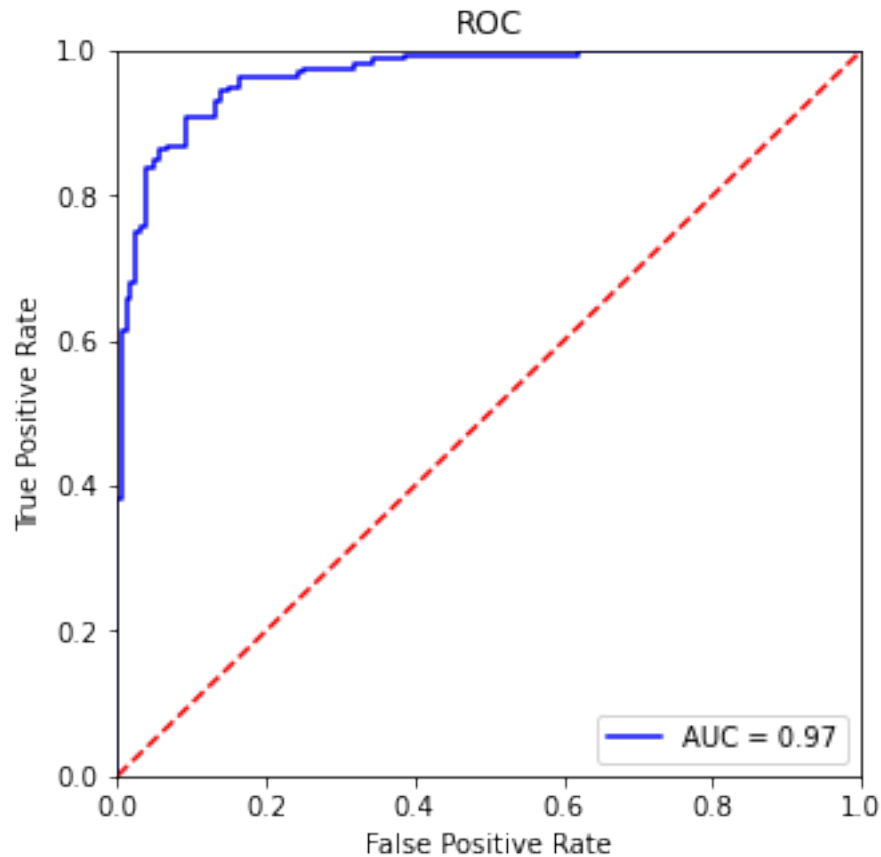


Apple__healthy



Apple_unhealthy





1.1.7 3. Create and compile model 2

This model uses compared to the previous model three convolution layers and two dense layers. The value of the neurons are decreased at each layer.

```
[14]: model2 = tf.keras.models.Sequential([
    tf.keras.layers.Conv2D(128, (3, 3), input_shape=(IMG_SIZE[0], IMG_SIZE[1], 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Conv2D(32, (3, 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(8, activation='relu', use_bias=False),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])
```

```
[15]: opt = tf.keras.optimizers.Adam(lr=LEARNING_RATE)
      model2.compile(optimizer=opt,
                    loss='categorical_crossentropy',
                    metrics=METRICS)
```

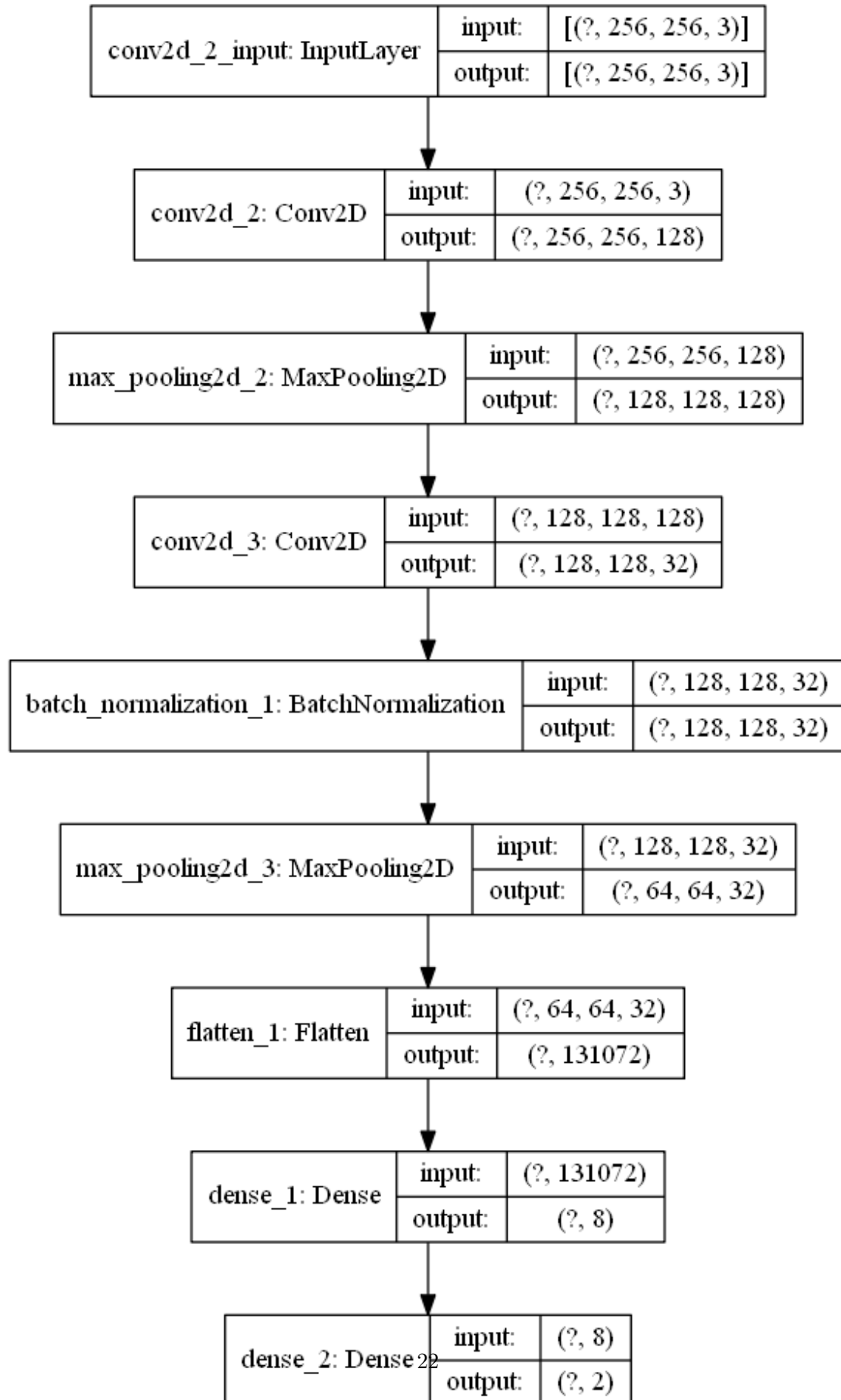
1.1.8 4. Display model structure 2

```
[16]: model2.summary()
      tf.keras.utils.plot_model(model2, show_shapes=True)
```

Model: "sequential_1"

Layer (type)	Output Shape	Param #
conv2d_2 (Conv2D)	(None, 256, 256, 128)	3456
max_pooling2d_2 (MaxPooling2D)	(None, 128, 128, 128)	0
conv2d_3 (Conv2D)	(None, 128, 128, 32)	36864
batch_normalization_1 (Batch Normalization)	(None, 128, 128, 32)	128
max_pooling2d_3 (MaxPooling2D)	(None, 64, 64, 32)	0
flatten_1 (Flatten)	(None, 131072)	0
dense_1 (Dense)	(None, 8)	1048576
dense_2 (Dense)	(None, 2)	18
Total params: 1,089,042		
Trainable params: 1,088,978		
Non-trainable params: 64		

```
[16]:
```



1.1.9 5. Training model 2

```
[17]: history2 = train_model(model2, "Model_2")
```

Epoch 1/25

46/46 [=====] - ETA: 0s - loss: 0.8180 - tp: 1580.0000
- fp: 592.0000 - tn: 1580.0000 - fn: 592.0000 - accuracy: 0.7274 - precision:
0.7274 - auc: 0.7974 - mae: 0.3428 - mse: 0.1960

Epoch 00001: val_accuracy improved from -inf to 0.48413, saving model to
./models\Model_2.hdf5

46/46 [=====] - 16s 354ms/step - loss: 0.8180 - tp:
1580.0000 - fp: 592.0000 - tn: 1580.0000 - fn: 592.0000 - accuracy: 0.7274 -
precision: 0.7274 - auc: 0.7974 - mae: 0.3428 - mse: 0.1960 - val_loss: 11.5489
- val_tp: 61.0000 - val_fp: 65.0000 - val_tn: 61.0000 - val_fn: 65.0000 -
val_accuracy: 0.4841 - val_precision: 0.4841 - val_auc: 0.4841 - val_mae: 0.5159
- val_mse: 0.5159

Epoch 2/25

46/46 [=====] - ETA: 0s - loss: 0.5592 - tp: 1234.0000
- fp: 224.0000 - tn: 1234.0000 - fn: 224.0000 - accuracy: 0.8464 - precision:
0.8464 - auc: 0.8797 - mae: 0.3452 - mse: 0.1751

Epoch 00002: val_accuracy improved from 0.48413 to 0.88889, saving model to
./models\Model_2.hdf5

46/46 [=====] - 16s 337ms/step - loss: 0.5592 - tp:
1234.0000 - fp: 224.0000 - tn: 1234.0000 - fn: 224.0000 - accuracy: 0.8464 -
precision: 0.8464 - auc: 0.8797 - mae: 0.3452 - mse: 0.1751 - val_loss: 0.5377 -
val_tp: 112.0000 - val_fp: 14.0000 - val_tn: 112.0000 - val_fn: 14.0000 -
val_accuracy: 0.8889 - val_precision: 0.8889 - val_auc: 0.9170 - val_mae: 0.4023
- val_mse: 0.1785

Epoch 3/25

46/46 [=====] - ETA: 0s - loss: 0.4701 - tp: 1274.0000
- fp: 184.0000 - tn: 1274.0000 - fn: 184.0000 - accuracy: 0.8738 - precision:
0.8738 - auc: 0.9104 - mae: 0.3157 - mse: 0.1527

Epoch 00003: val_accuracy did not improve from 0.88889

46/46 [=====] - 16s 339ms/step - loss: 0.4701 - tp:
1274.0000 - fp: 184.0000 - tn: 1274.0000 - fn: 184.0000 - accuracy: 0.8738 -
precision: 0.8738 - auc: 0.9104 - mae: 0.3157 - mse: 0.1527 - val_loss: 0.8873 -
val_tp: 84.0000 - val_fp: 42.0000 - val_tn: 84.0000 - val_fn: 42.0000 -
val_accuracy: 0.6667 - val_precision: 0.6667 - val_auc: 0.6559 - val_mae: 0.4268
- val_mse: 0.2545

Epoch 4/25

46/46 [=====] - ETA: 0s - loss: 0.4850 - tp: 1224.0000
- fp: 234.0000 - tn: 1224.0000 - fn: 234.0000 - accuracy: 0.8395 - precision:
0.8395 - auc: 0.8876 - mae: 0.3254 - mse: 0.1589

Epoch 00004: val_accuracy did not improve from 0.88889

46/46 [=====] - 15s 335ms/step - loss: 0.4850 - tp:

1224.0000 - fp: 234.0000 - tn: 1224.0000 - fn: 234.0000 - accuracy: 0.8395 -
precision: 0.8395 - auc: 0.8876 - mae: 0.3254 - mse: 0.1589 - val_loss: 0.8546 -
val_tp: 90.0000 - val_fp: 36.0000 - val_tn: 90.0000 - val_fn: 36.0000 -
val_accuracy: 0.7143 - val_precision: 0.7143 - val_auc: 0.7584 - val_mae: 0.3399
- val_mse: 0.2280

Epoch 5/25

46/46 [=====] - ETA: 0s - loss: 0.4612 - tp: 1269.0000
- fp: 189.0000 - tn: 1269.0000 - fn: 189.0000 - accuracy: 0.8704 - precision:
0.8704 - auc: 0.9101 - mae: 0.3040 - mse: 0.1434

Epoch 00005: val_accuracy improved from 0.88889 to 0.92857, saving model to
./models\Model_2.hdf5

46/46 [=====] - 15s 336ms/step - loss: 0.4612 - tp:
1269.0000 - fp: 189.0000 - tn: 1269.0000 - fn: 189.0000 - accuracy: 0.8704 -
precision: 0.8704 - auc: 0.9101 - mae: 0.3040 - mse: 0.1434 - val_loss: 0.3835 -
val_tp: 117.0000 - val_fp: 9.0000 - val_tn: 117.0000 - val_fn: 9.0000 -
val_accuracy: 0.9286 - val_precision: 0.9286 - val_auc: 0.9343 - val_mae: 0.2696
- val_mse: 0.1152

Epoch 6/25

46/46 [=====] - ETA: 0s - loss: 0.3830 - tp: 1331.0000
- fp: 127.0000 - tn: 1331.0000 - fn: 127.0000 - accuracy: 0.9129 - precision:
0.9129 - auc: 0.9413 - mae: 0.2718 - mse: 0.1207

Epoch 00006: val_accuracy did not improve from 0.92857

46/46 [=====] - 15s 336ms/step - loss: 0.3830 - tp:
1331.0000 - fp: 127.0000 - tn: 1331.0000 - fn: 127.0000 - accuracy: 0.9129 -
precision: 0.9129 - auc: 0.9413 - mae: 0.2718 - mse: 0.1207 - val_loss: 0.4319 -
val_tp: 110.0000 - val_fp: 16.0000 - val_tn: 110.0000 - val_fn: 16.0000 -
val_accuracy: 0.8730 - val_precision: 0.8730 - val_auc: 0.9484 - val_mae: 0.3325
- val_mse: 0.1346

Epoch 7/25

46/46 [=====] - ETA: 0s - loss: 0.3835 - tp: 1314.0000
- fp: 144.0000 - tn: 1314.0000 - fn: 144.0000 - accuracy: 0.9012 - precision:
0.9012 - auc: 0.9300 - mae: 0.2762 - mse: 0.1209

Epoch 00007: val_accuracy did not improve from 0.92857

46/46 [=====] - 15s 335ms/step - loss: 0.3835 - tp:
1314.0000 - fp: 144.0000 - tn: 1314.0000 - fn: 144.0000 - accuracy: 0.9012 -
precision: 0.9012 - auc: 0.9300 - mae: 0.2762 - mse: 0.1209 - val_loss: 0.4294 -
val_tp: 113.0000 - val_fp: 13.0000 - val_tn: 113.0000 - val_fn: 13.0000 -
val_accuracy: 0.8968 - val_precision: 0.8968 - val_auc: 0.9480 - val_mae: 0.3320
- val_mse: 0.1328

Epoch 8/25

46/46 [=====] - ETA: 0s - loss: 0.3530 - tp: 1325.0000
- fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 - precision:
0.9088 - auc: 0.9408 - mae: 0.2547 - mse: 0.1090

Epoch 00008: val_accuracy improved from 0.92857 to 0.94444, saving model to
./models\Model_2.hdf5

46/46 [=====] - 15s 336ms/step - loss: 0.3530 - tp:
1325.0000 - fp: 133.0000 - tn: 1325.0000 - fn: 133.0000 - accuracy: 0.9088 -
precision: 0.9088 - auc: 0.9408 - mae: 0.2547 - mse: 0.1090 - val_loss: 0.3448 -

val_tp: 119.0000 - val_fp: 7.0000 - val_tn: 119.0000 - val_fn: 7.0000 -
val_accuracy: 0.9444 - val_precision: 0.9444 - val_auc: 0.9713 - val_mae: 0.2721
- val_mse: 0.1005

Epoch 9/25

46/46 [=====] - ETA: 0s - loss: 0.3339 - tp: 1334.0000
- fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 - precision:
0.9150 - auc: 0.9473 - mae: 0.2421 - mse: 0.1015

Epoch 00009: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 335ms/step - loss: 0.3339 - tp:
1334.0000 - fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 -
precision: 0.9150 - auc: 0.9473 - mae: 0.2421 - mse: 0.1015 - val_loss: 0.4442 -
val_tp: 106.0000 - val_fp: 20.0000 - val_tn: 106.0000 - val_fn: 20.0000 -
val_accuracy: 0.8413 - val_precision: 0.8413 - val_auc: 0.8985 - val_mae: 0.3102
- val_mse: 0.1386

Epoch 10/25

46/46 [=====] - ETA: 0s - loss: 0.3172 - tp: 1346.0000
- fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 - precision:
0.9232 - auc: 0.9557 - mae: 0.2298 - mse: 0.0938

Epoch 00010: val_accuracy did not improve from 0.94444

46/46 [=====] - 16s 337ms/step - loss: 0.3172 - tp:
1346.0000 - fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 -
precision: 0.9232 - auc: 0.9557 - mae: 0.2298 - mse: 0.0938 - val_loss: 0.5493 -
val_tp: 87.0000 - val_fp: 39.0000 - val_tn: 87.0000 - val_fn: 39.0000 -
val_accuracy: 0.6905 - val_precision: 0.6905 - val_auc: 0.7952 - val_mae: 0.3870
- val_mse: 0.1885

Epoch 11/25

46/46 [=====] - ETA: 0s - loss: 0.3332 - tp: 1330.0000
- fp: 128.0000 - tn: 1330.0000 - fn: 128.0000 - accuracy: 0.9122 - precision:
0.9122 - auc: 0.9479 - mae: 0.2395 - mse: 0.0987

Epoch 00011: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 335ms/step - loss: 0.3332 - tp:
1330.0000 - fp: 128.0000 - tn: 1330.0000 - fn: 128.0000 - accuracy: 0.9122 -
precision: 0.9122 - auc: 0.9479 - mae: 0.2395 - mse: 0.0987 - val_loss: 0.6907 -
val_tp: 108.0000 - val_fp: 18.0000 - val_tn: 108.0000 - val_fn: 18.0000 -
val_accuracy: 0.8571 - val_precision: 0.8571 - val_auc: 0.8819 - val_mae: 0.2301
- val_mse: 0.1398

Epoch 12/25

46/46 [=====] - ETA: 0s - loss: 0.3199 - tp: 1335.0000
- fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 - precision:
0.9156 - auc: 0.9486 - mae: 0.2272 - mse: 0.0931

Epoch 00012: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 336ms/step - loss: 0.3199 - tp:
1335.0000 - fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 -
precision: 0.9156 - auc: 0.9486 - mae: 0.2272 - mse: 0.0931 - val_loss: 0.7037 -
val_tp: 72.0000 - val_fp: 54.0000 - val_tn: 72.0000 - val_fn: 54.0000 -
val_accuracy: 0.5714 - val_precision: 0.5714 - val_auc: 0.6121 - val_mae: 0.4574
- val_mse: 0.2561

Epoch 13/25

46/46 [=====] - ETA: 0s - loss: 0.3111 - tp: 1338.0000
- fp: 120.0000 - tn: 1338.0000 - fn: 120.0000 - accuracy: 0.9177 - precision:
0.9177 - auc: 0.9517 - mae: 0.2199 - mse: 0.0882
Epoch 00013: val_accuracy did not improve from 0.94444
46/46 [=====] - 15s 335ms/step - loss: 0.3111 - tp:
1338.0000 - fp: 120.0000 - tn: 1338.0000 - fn: 120.0000 - accuracy: 0.9177 -
precision: 0.9177 - auc: 0.9517 - mae: 0.2199 - mse: 0.0882 - val_loss: 0.4113 -
val_tp: 107.0000 - val_fp: 19.0000 - val_tn: 107.0000 - val_fn: 19.0000 -
val_accuracy: 0.8492 - val_precision: 0.8492 - val_auc: 0.8931 - val_mae: 0.2981
- val_mse: 0.1286
Epoch 14/25
46/46 [=====] - ETA: 0s - loss: 0.2926 - tp: 1335.0000
- fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 - precision:
0.9156 - auc: 0.9598 - mae: 0.2108 - mse: 0.0833
Epoch 00014: val_accuracy did not improve from 0.94444
46/46 [=====] - 15s 335ms/step - loss: 0.2926 - tp:
1335.0000 - fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 -
precision: 0.9156 - auc: 0.9598 - mae: 0.2108 - mse: 0.0833 - val_loss: 0.6181 -
val_tp: 85.0000 - val_fp: 41.0000 - val_tn: 85.0000 - val_fn: 41.0000 -
val_accuracy: 0.6746 - val_precision: 0.6746 - val_auc: 0.7448 - val_mae: 0.3707
- val_mse: 0.2072
Epoch 15/25
46/46 [=====] - ETA: 0s - loss: 0.3331 - tp: 1310.0000
- fp: 148.0000 - tn: 1310.0000 - fn: 148.0000 - accuracy: 0.8985 - precision:
0.8985 - auc: 0.9425 - mae: 0.2254 - mse: 0.0952
Epoch 00015: val_accuracy did not improve from 0.94444
46/46 [=====] - 15s 335ms/step - loss: 0.3331 - tp:
1310.0000 - fp: 148.0000 - tn: 1310.0000 - fn: 148.0000 - accuracy: 0.8985 -
precision: 0.8985 - auc: 0.9425 - mae: 0.2254 - mse: 0.0952 - val_loss: 0.4028 -
val_tp: 105.0000 - val_fp: 21.0000 - val_tn: 105.0000 - val_fn: 21.0000 -
val_accuracy: 0.8333 - val_precision: 0.8333 - val_auc: 0.8936 - val_mae: 0.2234
- val_mse: 0.1284
Epoch 16/25
46/46 [=====] - ETA: 0s - loss: 0.3090 - tp: 1315.0000
- fp: 143.0000 - tn: 1315.0000 - fn: 143.0000 - accuracy: 0.9019 - precision:
0.9019 - auc: 0.9472 - mae: 0.2170 - mse: 0.0898
Epoch 00016: val_accuracy did not improve from 0.94444
46/46 [=====] - 15s 335ms/step - loss: 0.3090 - tp:
1315.0000 - fp: 143.0000 - tn: 1315.0000 - fn: 143.0000 - accuracy: 0.9019 -
precision: 0.9019 - auc: 0.9472 - mae: 0.2170 - mse: 0.0898 - val_loss: 0.6671 -
val_tp: 80.0000 - val_fp: 46.0000 - val_tn: 80.0000 - val_fn: 46.0000 -
val_accuracy: 0.6349 - val_precision: 0.6349 - val_auc: 0.6887 - val_mae: 0.4182
- val_mse: 0.2394
Epoch 17/25
46/46 [=====] - ETA: 0s - loss: 0.2646 - tp: 1358.0000
- fp: 100.0000 - tn: 1358.0000 - fn: 100.0000 - accuracy: 0.9314 - precision:
0.9314 - auc: 0.9622 - mae: 0.1869 - mse: 0.0720
Epoch 00017: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 336ms/step - loss: 0.2646 - tp: 1358.0000 - fp: 100.0000 - tn: 1358.0000 - fn: 100.0000 - accuracy: 0.9314 - precision: 0.9314 - auc: 0.9622 - mae: 0.1869 - mse: 0.0720 - val_loss: 0.6741 - val_tp: 106.0000 - val_fp: 20.0000 - val_tn: 106.0000 - val_fn: 20.0000 - val_accuracy: 0.8413 - val_precision: 0.8413 - val_auc: 0.8696 - val_mae: 0.2773 - val_mse: 0.1349

Epoch 18/25

46/46 [=====] - ETA: 0s - loss: 0.2845 - tp: 1351.0000 - fp: 107.0000 - tn: 1351.0000 - fn: 107.0000 - accuracy: 0.9266 - precision: 0.9266 - auc: 0.9579 - mae: 0.1917 - mse: 0.0746

Epoch 00018: val_accuracy did not improve from 0.94444

46/46 [=====] - 15s 336ms/step - loss: 0.2845 - tp: 1351.0000 - fp: 107.0000 - tn: 1351.0000 - fn: 107.0000 - accuracy: 0.9266 - precision: 0.9266 - auc: 0.9579 - mae: 0.1917 - mse: 0.0746 - val_loss: 1.5093 - val_tp: 81.0000 - val_fp: 45.0000 - val_tn: 81.0000 - val_fn: 45.0000 - val_accuracy: 0.6429 - val_precision: 0.6429 - val_auc: 0.7387 - val_mae: 0.3611 - val_mse: 0.3136

Epoch 19/25

46/46 [=====] - ETA: 0s - loss: 0.2742 - tp: 1343.0000 - fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 - precision: 0.9211 - auc: 0.9580 - mae: 0.1883 - mse: 0.0743

Epoch 00019: val_accuracy improved from 0.94444 to 0.97619, saving model to ./models\Model_2.hdf5

46/46 [=====] - 16s 339ms/step - loss: 0.2742 - tp: 1343.0000 - fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 - precision: 0.9211 - auc: 0.9580 - mae: 0.1883 - mse: 0.0743 - val_loss: 0.1743 - val_tp: 123.0000 - val_fp: 3.0000 - val_tn: 123.0000 - val_fn: 3.0000 - val_accuracy: 0.9762 - val_precision: 0.9762 - val_auc: 0.9895 - val_mae: 0.1411 - val_mse: 0.0430

Epoch 20/25

46/46 [=====] - ETA: 0s - loss: 0.2490 - tp: 1352.0000 - fp: 106.0000 - tn: 1352.0000 - fn: 106.0000 - accuracy: 0.9273 - precision: 0.9273 - auc: 0.9652 - mae: 0.1790 - mse: 0.0681

Epoch 00020: val_accuracy did not improve from 0.97619

46/46 [=====] - 15s 337ms/step - loss: 0.2490 - tp: 1352.0000 - fp: 106.0000 - tn: 1352.0000 - fn: 106.0000 - accuracy: 0.9273 - precision: 0.9273 - auc: 0.9652 - mae: 0.1790 - mse: 0.0681 - val_loss: 0.3980 - val_tp: 108.0000 - val_fp: 18.0000 - val_tn: 108.0000 - val_fn: 18.0000 - val_accuracy: 0.8571 - val_precision: 0.8571 - val_auc: 0.9278 - val_mae: 0.1885 - val_mse: 0.1042

Epoch 21/25

46/46 [=====] - ETA: 0s - loss: 0.2451 - tp: 1348.0000 - fp: 110.0000 - tn: 1348.0000 - fn: 110.0000 - accuracy: 0.9246 - precision: 0.9246 - auc: 0.9648 - mae: 0.1736 - mse: 0.0666

Epoch 00021: val_accuracy did not improve from 0.97619

46/46 [=====] - 15s 336ms/step - loss: 0.2451 - tp: 1348.0000 - fp: 110.0000 - tn: 1348.0000 - fn: 110.0000 - accuracy: 0.9246 - precision: 0.9246 - auc: 0.9648 - mae: 0.1736 - mse: 0.0666 - val_loss: 0.3403 -

val_tp: 110.0000 - val_fp: 16.0000 - val_tn: 110.0000 - val_fn: 16.0000 -
val_accuracy: 0.8730 - val_precision: 0.8730 - val_auc: 0.9234 - val_mae: 0.2310
- val_mse: 0.1042

Epoch 22/25

46/46 [=====] - ETA: 0s - loss: 0.2635 - tp: 1335.0000
- fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 - precision:
0.9156 - auc: 0.9603 - mae: 0.1823 - mse: 0.0727

Epoch 00022: val_accuracy did not improve from 0.97619

46/46 [=====] - 16s 354ms/step - loss: 0.2635 - tp:
1335.0000 - fp: 123.0000 - tn: 1335.0000 - fn: 123.0000 - accuracy: 0.9156 -
precision: 0.9156 - auc: 0.9603 - mae: 0.1823 - mse: 0.0727 - val_loss: 0.3381 -
val_tp: 110.0000 - val_fp: 16.0000 - val_tn: 110.0000 - val_fn: 16.0000 -
val_accuracy: 0.8730 - val_precision: 0.8730 - val_auc: 0.9349 - val_mae: 0.2227
- val_mse: 0.1006

Epoch 23/25

46/46 [=====] - ETA: 0s - loss: 0.2399 - tp: 1345.0000
- fp: 113.0000 - tn: 1345.0000 - fn: 113.0000 - accuracy: 0.9225 - precision:
0.9225 - auc: 0.9683 - mae: 0.1708 - mse: 0.0656

Epoch 00023: val_accuracy did not improve from 0.97619

46/46 [=====] - 16s 357ms/step - loss: 0.2399 - tp:
1345.0000 - fp: 113.0000 - tn: 1345.0000 - fn: 113.0000 - accuracy: 0.9225 -
precision: 0.9225 - auc: 0.9683 - mae: 0.1708 - mse: 0.0656 - val_loss: 0.1948 -
val_tp: 121.0000 - val_fp: 5.0000 - val_tn: 121.0000 - val_fn: 5.0000 -
val_accuracy: 0.9603 - val_precision: 0.9603 - val_auc: 0.9829 - val_mae: 0.1504
- val_mse: 0.0491

Epoch 24/25

46/46 [=====] - ETA: 0s - loss: 0.2341 - tp: 1352.0000
- fp: 106.0000 - tn: 1352.0000 - fn: 106.0000 - accuracy: 0.9273 - precision:
0.9273 - auc: 0.9686 - mae: 0.1613 - mse: 0.0626

Epoch 00024: val_accuracy did not improve from 0.97619

46/46 [=====] - 16s 351ms/step - loss: 0.2341 - tp:
1352.0000 - fp: 106.0000 - tn: 1352.0000 - fn: 106.0000 - accuracy: 0.9273 -
precision: 0.9273 - auc: 0.9686 - mae: 0.1613 - mse: 0.0626 - val_loss: 0.2578 -
val_tp: 114.0000 - val_fp: 12.0000 - val_tn: 114.0000 - val_fn: 12.0000 -
val_accuracy: 0.9048 - val_precision: 0.9048 - val_auc: 0.9569 - val_mae: 0.1545
- val_mse: 0.0766

Epoch 25/25

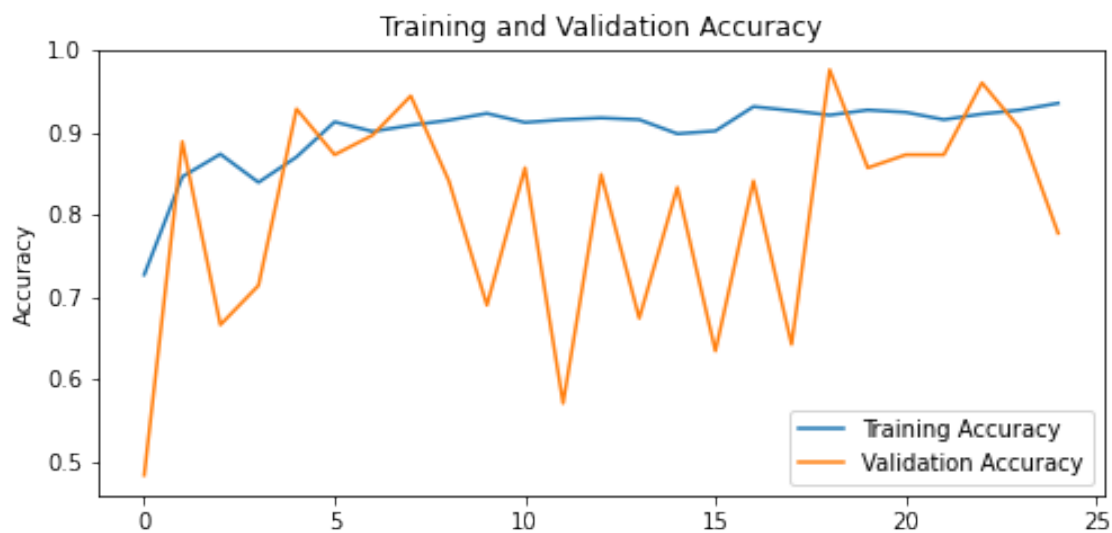
46/46 [=====] - ETA: 0s - loss: 0.2216 - tp: 1364.0000
- fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 - precision:
0.9355 - auc: 0.9732 - mae: 0.1598 - mse: 0.0584

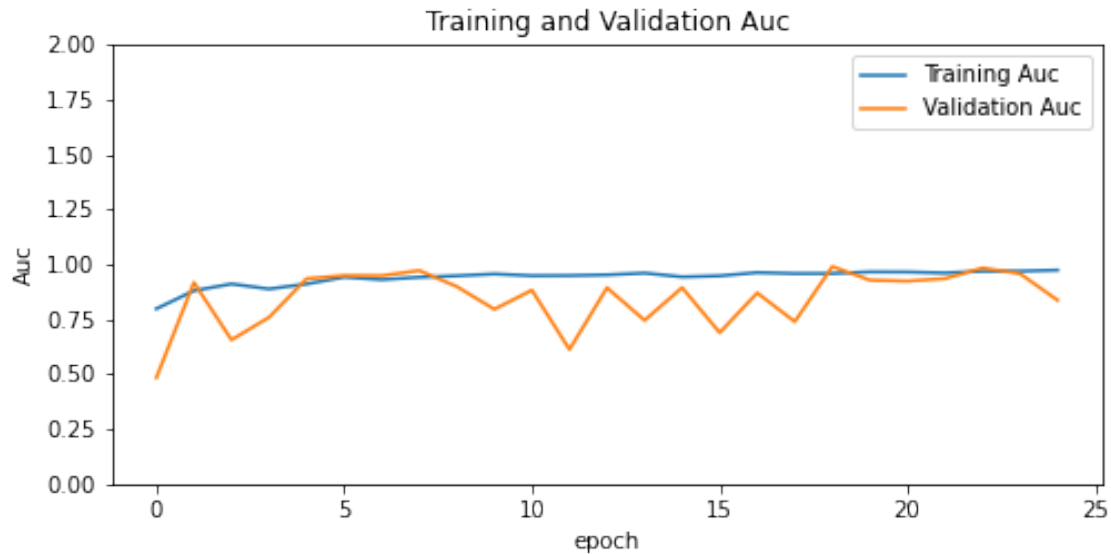
Epoch 00025: val_accuracy did not improve from 0.97619

46/46 [=====] - 16s 352ms/step - loss: 0.2216 - tp:
1364.0000 - fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 -
precision: 0.9355 - auc: 0.9732 - mae: 0.1598 - mse: 0.0584 - val_loss: 0.7747 -
val_tp: 98.0000 - val_fp: 28.0000 - val_tn: 98.0000 - val_fn: 28.0000 -
val_accuracy: 0.7778 - val_precision: 0.7778 - val_auc: 0.8361 - val_mae: 0.2513
- val_mse: 0.1886

1.1.10 6. Display History 2

```
[18]: print_history(history2)
```





1.1.11 7. Evaluate the model 2

```
[19]: print_model_evaluation(model2);
```

```
714/714 [=====] - 3s 5ms/step - loss: 1.6439 - tp:
505.0000 - fp: 209.0000 - tn: 505.0000 - fn: 209.0000 - accuracy: 0.7073 -
precision: 0.7073 - auc: 0.7633 - mae: 0.2996 - mse: 0.2625
loss : 1.644
tp : 505.0
fp : 209.0
tn : 505.0
fn : 209.0
accuracy : 0.707
precision : 0.707
auc : 0.763
mae : 0.3
mse : 0.262
```

1.1.12 8. Predict with model 2

```
[20]: predict_and_print_roc(model2);
```

Label Predictions:

```
[0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0,
0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0,
1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0,
0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0,
0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 0]
```

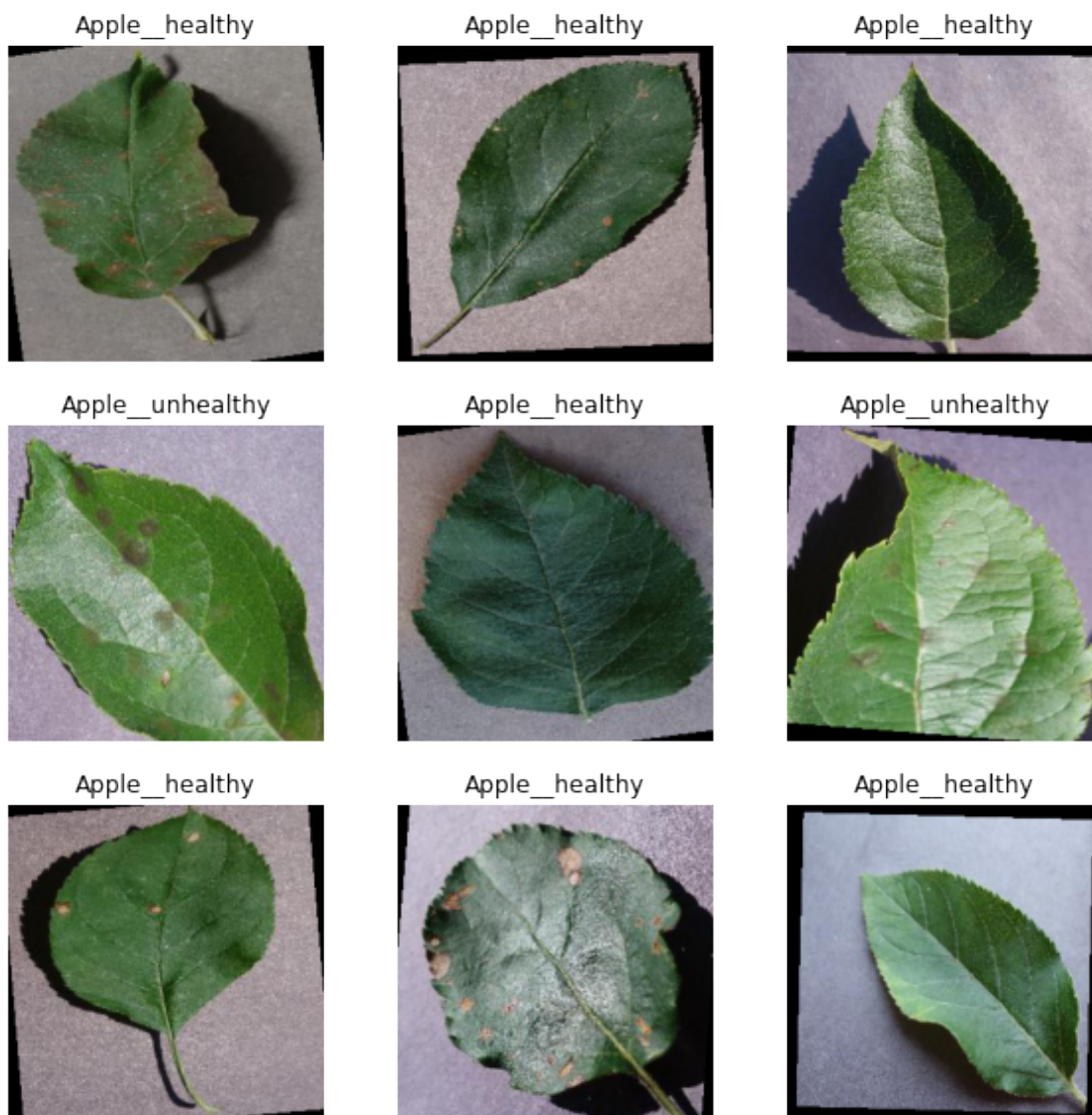
Real Labels:

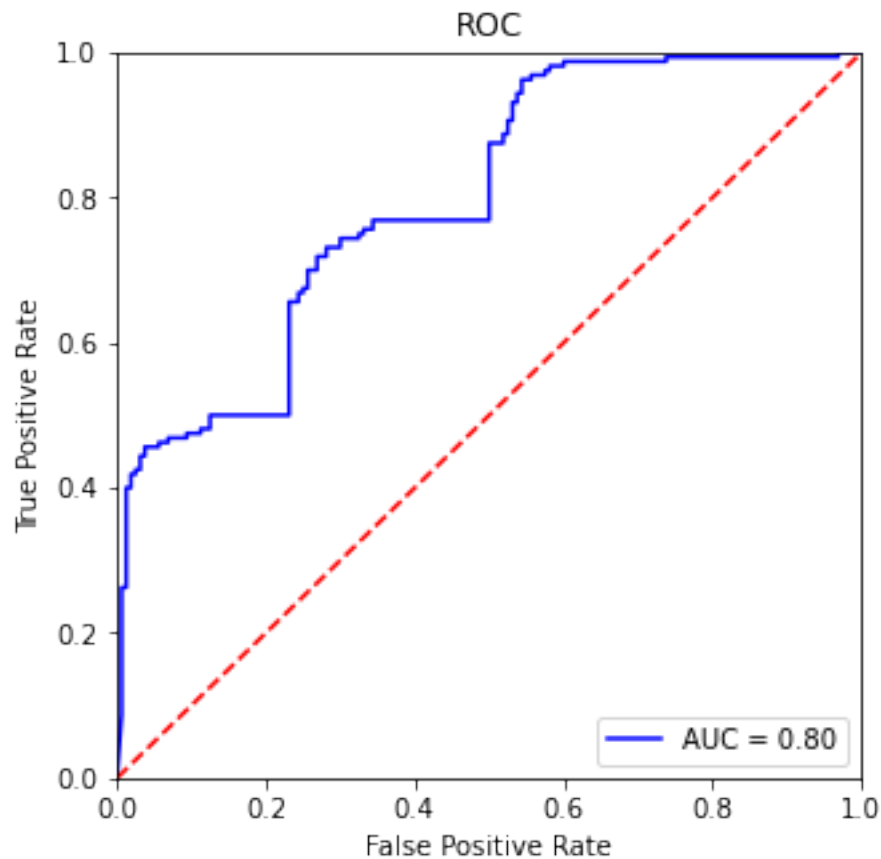
```
[1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0,
0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 1, 0,
1, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1, 0, 1,
1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 1,
0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 1, 1, 0, 0, 1,
0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 1, 0, 1, 0]
```

Confusion Matrix:

```
[[80  0]
 [45 35]]
```

Accuracy: 0.72





1.1.13 3. Create and compile model 3

This model has like the previous model three convolution layers. It starts with a small number of neurons and gradually increases its neuron amount. In between every convolution layer, a max pooling layer manipulates the values. Additionally, 20% of random values are dropped at the end of the hidden layers. The result from the hidden layers is then flattened with three dense layers that again gradually become smaller.

```
[21]: model3 = tf.keras.models.Sequential([
    tf.keras.layers.Conv2D(32, (3, 3), input_shape=(IMG_SIZE[0], IMG_SIZE[1], 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Conv2D(64, (3, 3),
        padding='same', activation='relu', use_bias=False),
    tf.keras.layers.MaxPooling2D((2, 2)),
    tf.keras.layers.Conv2D(128, (3, 3),
        padding='same', activation='relu', use_bias=False),
```



```

tf.keras.layers.Dropout(0.2),
tf.keras.layers.BatchNormalization(),
tf.keras.layers.MaxPooling2D((2, 2)),
tf.keras.layers.Flatten(),
tf.keras.layers.Dense(16, activation='relu', use_bias=False),
tf.keras.layers.Dense(8, activation='relu', use_bias=False),
tf.keras.layers.Dense(num_classes, activation='softmax')
])

```

```

[22]: opt = tf.keras.optimizers.Adam(lr=LEARNING_RATE)
model3.compile(optimizer=opt,
               loss='categorical_crossentropy',
               metrics=METRICS)

```

1.1.14 4. Display model structure 3

```

[23]: model3.summary()
tf.keras.utils.plot_model(model3, show_shapes=True)

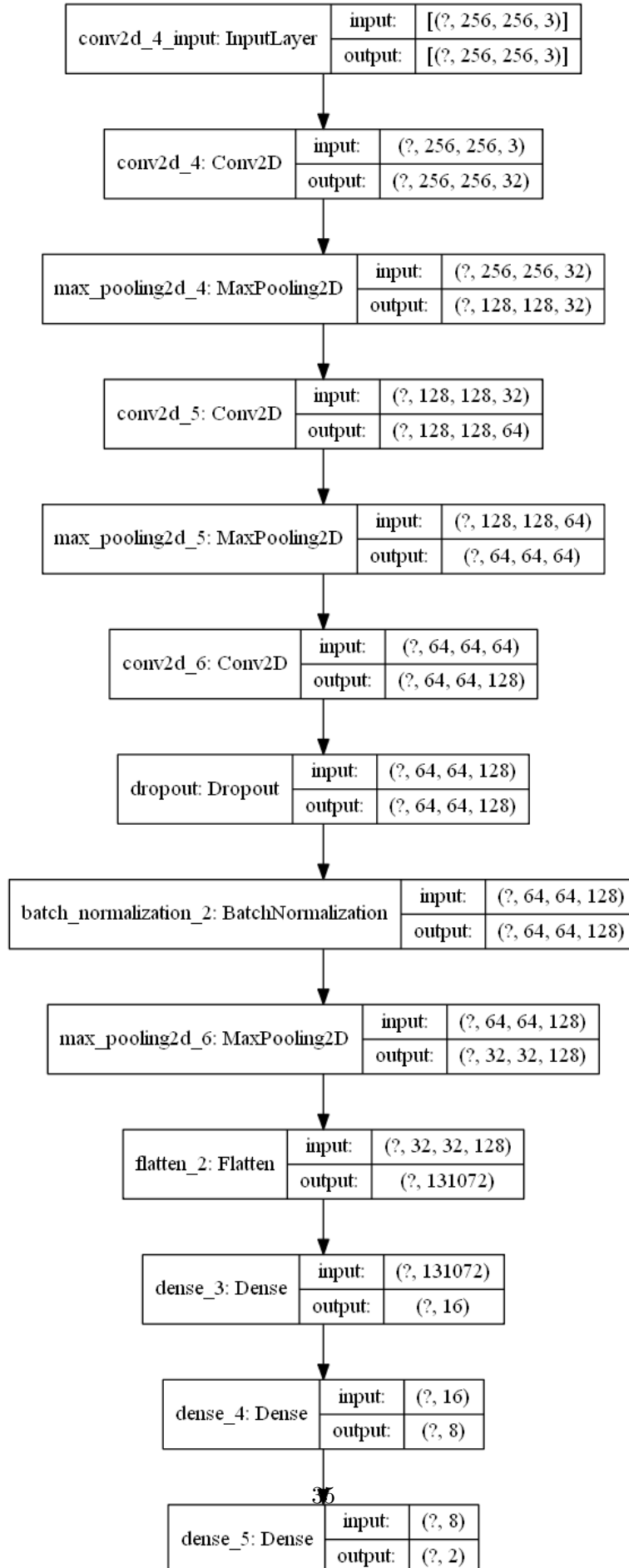
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
conv2d_4 (Conv2D)	(None, 256, 256, 32)	864
max_pooling2d_4 (MaxPooling2D)	(None, 128, 128, 32)	0
conv2d_5 (Conv2D)	(None, 128, 128, 64)	18432
max_pooling2d_5 (MaxPooling2D)	(None, 64, 64, 64)	0
conv2d_6 (Conv2D)	(None, 64, 64, 128)	73728
dropout (Dropout)	(None, 64, 64, 128)	0
batch_normalization_2 (Batch Normalization)	(None, 64, 64, 128)	512
max_pooling2d_6 (MaxPooling2D)	(None, 32, 32, 128)	0
flatten_2 (Flatten)	(None, 131072)	0
dense_3 (Dense)	(None, 16)	2097152
dense_4 (Dense)	(None, 8)	128
dense_5 (Dense)	(None, 2)	18

Total params: 2,190,834
Trainable params: 2,190,578
Non-trainable params: 256

[23]:



1.1.15 5. Training model 3

```
[24]: history3 = train_model(model3, "Model_3")
```

Epoch 1/25

46/46 [=====] - ETA: 0s - loss: 0.8121 - tp: 1501.0000
- fp: 671.0000 - tn: 1501.0000 - fn: 671.0000 - accuracy: 0.6911 - precision:
0.6911 - auc: 0.7374 - mae: 0.3396 - mse: 0.2369

Epoch 00001: val_accuracy improved from -inf to 0.62698, saving model to
./models\Model_3.hdf5

46/46 [=====] - 17s 362ms/step - loss: 0.8121 - tp:
1501.0000 - fp: 671.0000 - tn: 1501.0000 - fn: 671.0000 - accuracy: 0.6911 -
precision: 0.6911 - auc: 0.7374 - mae: 0.3396 - mse: 0.2369 - val_loss: 0.6015 -
val_tp: 79.0000 - val_fp: 47.0000 - val_tn: 79.0000 - val_fn: 47.0000 -
val_accuracy: 0.6270 - val_precision: 0.6270 - val_auc: 0.7532 - val_mae: 0.4324
- val_mse: 0.2077

Epoch 2/25

46/46 [=====] - ETA: 0s - loss: 0.3401 - tp: 1256.0000
- fp: 202.0000 - tn: 1256.0000 - fn: 202.0000 - accuracy: 0.8615 - precision:
0.8615 - auc: 0.9323 - mae: 0.1857 - mse: 0.1016

Epoch 00002: val_accuracy improved from 0.62698 to 0.91270, saving model to
./models\Model_3.hdf5

46/46 [=====] - 16s 338ms/step - loss: 0.3401 - tp:
1256.0000 - fp: 202.0000 - tn: 1256.0000 - fn: 202.0000 - accuracy: 0.8615 -
precision: 0.8615 - auc: 0.9323 - mae: 0.1857 - mse: 0.1016 - val_loss: 0.5345 -
val_tp: 115.0000 - val_fp: 11.0000 - val_tn: 115.0000 - val_fn: 11.0000 -
val_accuracy: 0.9127 - val_precision: 0.9127 - val_auc: 0.9680 - val_mae: 0.4099
- val_mse: 0.1729

Epoch 3/25

46/46 [=====] - ETA: 0s - loss: 0.3202 - tp: 1280.0000
- fp: 178.0000 - tn: 1280.0000 - fn: 178.0000 - accuracy: 0.8779 - precision:
0.8779 - auc: 0.9448 - mae: 0.1613 - mse: 0.0889

Epoch 00003: val_accuracy did not improve from 0.91270

46/46 [=====] - 15s 337ms/step - loss: 0.3202 - tp:
1280.0000 - fp: 178.0000 - tn: 1280.0000 - fn: 178.0000 - accuracy: 0.8779 -
precision: 0.8779 - auc: 0.9448 - mae: 0.1613 - mse: 0.0889 - val_loss: 0.4538 -
val_tp: 111.0000 - val_fp: 15.0000 - val_tn: 111.0000 - val_fn: 15.0000 -
val_accuracy: 0.8810 - val_precision: 0.8810 - val_auc: 0.9570 - val_mae: 0.3522
- val_mse: 0.1402

Epoch 4/25

46/46 [=====] - ETA: 0s - loss: 0.2811 - tp: 1303.0000
- fp: 155.0000 - tn: 1303.0000 - fn: 155.0000 - accuracy: 0.8937 - precision:
0.8937 - auc: 0.9547 - mae: 0.1499 - mse: 0.0812

Epoch 00004: val_accuracy did not improve from 0.91270

46/46 [=====] - 15s 337ms/step - loss: 0.2811 - tp:

1303.0000 - fp: 155.0000 - tn: 1303.0000 - fn: 155.0000 - accuracy: 0.8937 -
precision: 0.8937 - auc: 0.9547 - mae: 0.1499 - mse: 0.0812 - val_loss: 0.6074 -
val_tp: 86.0000 - val_fp: 40.0000 - val_tn: 86.0000 - val_fn: 40.0000 -
val_accuracy: 0.6825 - val_precision: 0.6825 - val_auc: 0.7667 - val_mae: 0.3590
- val_mse: 0.2125

Epoch 5/25

46/46 [=====] - ETA: 0s - loss: 0.3079 - tp: 1271.0000
- fp: 187.0000 - tn: 1271.0000 - fn: 187.0000 - accuracy: 0.8717 - precision:
0.8717 - auc: 0.9470 - mae: 0.1603 - mse: 0.0913

Epoch 00005: val_accuracy did not improve from 0.91270

46/46 [=====] - 15s 336ms/step - loss: 0.3079 - tp:
1271.0000 - fp: 187.0000 - tn: 1271.0000 - fn: 187.0000 - accuracy: 0.8717 -
precision: 0.8717 - auc: 0.9470 - mae: 0.1603 - mse: 0.0913 - val_loss: 0.3906 -
val_tp: 107.0000 - val_fp: 19.0000 - val_tn: 107.0000 - val_fn: 19.0000 -
val_accuracy: 0.8492 - val_precision: 0.8492 - val_auc: 0.9219 - val_mae: 0.2807
- val_mse: 0.1219

Epoch 6/25

46/46 [=====] - ETA: 0s - loss: 0.2809 - tp: 1299.0000
- fp: 159.0000 - tn: 1299.0000 - fn: 159.0000 - accuracy: 0.8909 - precision:
0.8909 - auc: 0.9549 - mae: 0.1402 - mse: 0.0804

Epoch 00006: val_accuracy did not improve from 0.91270

46/46 [=====] - 15s 335ms/step - loss: 0.2809 - tp:
1299.0000 - fp: 159.0000 - tn: 1299.0000 - fn: 159.0000 - accuracy: 0.8909 -
precision: 0.8909 - auc: 0.9549 - mae: 0.1402 - mse: 0.0804 - val_loss: 0.4129 -
val_tp: 104.0000 - val_fp: 22.0000 - val_tn: 104.0000 - val_fn: 22.0000 -
val_accuracy: 0.8254 - val_precision: 0.8254 - val_auc: 0.9010 - val_mae: 0.2456
- val_mse: 0.1286

Epoch 7/25

46/46 [=====] - ETA: 0s - loss: 0.2393 - tp: 1339.0000
- fp: 119.0000 - tn: 1339.0000 - fn: 119.0000 - accuracy: 0.9184 - precision:
0.9184 - auc: 0.9673 - mae: 0.1159 - mse: 0.0667

Epoch 00007: val_accuracy did not improve from 0.91270

46/46 [=====] - 16s 338ms/step - loss: 0.2393 - tp:
1339.0000 - fp: 119.0000 - tn: 1339.0000 - fn: 119.0000 - accuracy: 0.9184 -
precision: 0.9184 - auc: 0.9673 - mae: 0.1159 - mse: 0.0667 - val_loss: 0.4825 -
val_tp: 96.0000 - val_fp: 30.0000 - val_tn: 96.0000 - val_fn: 30.0000 -
val_accuracy: 0.7619 - val_precision: 0.7619 - val_auc: 0.8814 - val_mae: 0.2445
- val_mse: 0.1524

Epoch 8/25

46/46 [=====] - ETA: 0s - loss: 0.2732 - tp: 1305.0000
- fp: 153.0000 - tn: 1305.0000 - fn: 153.0000 - accuracy: 0.8951 - precision:
0.8951 - auc: 0.9573 - mae: 0.1351 - mse: 0.0782

Epoch 00008: val_accuracy improved from 0.91270 to 0.96825, saving model to
./models\Model_3.hdf5

46/46 [=====] - 16s 339ms/step - loss: 0.2732 - tp:
1305.0000 - fp: 153.0000 - tn: 1305.0000 - fn: 153.0000 - accuracy: 0.8951 -
precision: 0.8951 - auc: 0.9573 - mae: 0.1351 - mse: 0.0782 - val_loss: 0.2745 -
val_tp: 122.0000 - val_fp: 4.0000 - val_tn: 122.0000 - val_fn: 4.0000 -

val_accuracy: 0.9683 - val_precision: 0.9683 - val_auc: 0.9731 - val_mae: 0.1160
- val_mse: 0.0474
Epoch 9/25
46/46 [=====] - ETA: 0s - loss: 0.2525 - tp: 1317.0000
- fp: 141.0000 - tn: 1317.0000 - fn: 141.0000 - accuracy: 0.9033 - precision:
0.9033 - auc: 0.9622 - mae: 0.1328 - mse: 0.0715
Epoch 00009: val_accuracy did not improve from 0.96825
46/46 [=====] - 16s 337ms/step - loss: 0.2525 - tp:
1317.0000 - fp: 141.0000 - tn: 1317.0000 - fn: 141.0000 - accuracy: 0.9033 -
precision: 0.9033 - auc: 0.9622 - mae: 0.1328 - mse: 0.0715 - val_loss: 0.5060 -
val_tp: 98.0000 - val_fp: 28.0000 - val_tn: 98.0000 - val_fn: 28.0000 -
val_accuracy: 0.7778 - val_precision: 0.7778 - val_auc: 0.8970 - val_mae: 0.2242
- val_mse: 0.1600
Epoch 10/25
46/46 [=====] - ETA: 0s - loss: 0.2185 - tp: 1337.0000
- fp: 121.0000 - tn: 1337.0000 - fn: 121.0000 - accuracy: 0.9170 - precision:
0.9170 - auc: 0.9716 - mae: 0.1174 - mse: 0.0633
Epoch 00010: val_accuracy did not improve from 0.96825
46/46 [=====] - 16s 338ms/step - loss: 0.2185 - tp:
1337.0000 - fp: 121.0000 - tn: 1337.0000 - fn: 121.0000 - accuracy: 0.9170 -
precision: 0.9170 - auc: 0.9716 - mae: 0.1174 - mse: 0.0633 - val_loss: 0.6459 -
val_tp: 92.0000 - val_fp: 34.0000 - val_tn: 92.0000 - val_fn: 34.0000 -
val_accuracy: 0.7302 - val_precision: 0.7302 - val_auc: 0.8607 - val_mae: 0.2701
- val_mse: 0.2060
Epoch 11/25
46/46 [=====] - ETA: 0s - loss: 0.2132 - tp: 1348.0000
- fp: 110.0000 - tn: 1348.0000 - fn: 110.0000 - accuracy: 0.9246 - precision:
0.9246 - auc: 0.9725 - mae: 0.1110 - mse: 0.0578
Epoch 00011: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 337ms/step - loss: 0.2132 - tp:
1348.0000 - fp: 110.0000 - tn: 1348.0000 - fn: 110.0000 - accuracy: 0.9246 -
precision: 0.9246 - auc: 0.9725 - mae: 0.1110 - mse: 0.0578 - val_loss: 0.3528 -
val_tp: 112.0000 - val_fp: 14.0000 - val_tn: 112.0000 - val_fn: 14.0000 -
val_accuracy: 0.8889 - val_precision: 0.8889 - val_auc: 0.9573 - val_mae: 0.1287
- val_mse: 0.0844
Epoch 12/25
46/46 [=====] - ETA: 0s - loss: 0.2079 - tp: 1341.0000
- fp: 117.0000 - tn: 1341.0000 - fn: 117.0000 - accuracy: 0.9198 - precision:
0.9198 - auc: 0.9744 - mae: 0.1110 - mse: 0.0605
Epoch 00012: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 336ms/step - loss: 0.2079 - tp:
1341.0000 - fp: 117.0000 - tn: 1341.0000 - fn: 117.0000 - accuracy: 0.9198 -
precision: 0.9198 - auc: 0.9744 - mae: 0.1110 - mse: 0.0605 - val_loss: 0.8218 -
val_tp: 112.0000 - val_fp: 14.0000 - val_tn: 112.0000 - val_fn: 14.0000 -
val_accuracy: 0.8889 - val_precision: 0.8889 - val_auc: 0.9178 - val_mae: 0.1395
- val_mse: 0.0951
Epoch 13/25
46/46 [=====] - ETA: 0s - loss: 0.1739 - tp: 1362.0000

- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision: 0.9342 - auc: 0.9810 - mae: 0.0967 - mse: 0.0499
Epoch 00013: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 337ms/step - loss: 0.1739 - tp: 1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision: 0.9342 - auc: 0.9810 - mae: 0.0967 - mse: 0.0499 - val_loss: 0.2048 - val_tp: 118.0000 - val_fp: 8.0000 - val_tn: 118.0000 - val_fn: 8.0000 - val_accuracy: 0.9365 - val_precision: 0.9365 - val_auc: 0.9746 - val_mae: 0.1165 - val_mse: 0.0510
Epoch 14/25
46/46 [=====] - ETA: 0s - loss: 0.1902 - tp: 1356.0000 - fp: 102.0000 - tn: 1356.0000 - fn: 102.0000 - accuracy: 0.9300 - precision: 0.9300 - auc: 0.9773 - mae: 0.1014 - mse: 0.0542
Epoch 00014: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 336ms/step - loss: 0.1902 - tp: 1356.0000 - fp: 102.0000 - tn: 1356.0000 - fn: 102.0000 - accuracy: 0.9300 - precision: 0.9300 - auc: 0.9773 - mae: 0.1014 - mse: 0.0542 - val_loss: 0.1060 - val_tp: 122.0000 - val_fp: 4.0000 - val_tn: 122.0000 - val_fn: 4.0000 - val_accuracy: 0.9683 - val_precision: 0.9683 - val_auc: 0.9923 - val_mae: 0.0735 - val_mse: 0.0265
Epoch 15/25
46/46 [=====] - ETA: 0s - loss: 0.1806 - tp: 1364.0000 - fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 - precision: 0.9355 - auc: 0.9796 - mae: 0.0967 - mse: 0.0519
Epoch 00015: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 337ms/step - loss: 0.1806 - tp: 1364.0000 - fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 - precision: 0.9355 - auc: 0.9796 - mae: 0.0967 - mse: 0.0519 - val_loss: 0.5205 - val_tp: 111.0000 - val_fp: 15.0000 - val_tn: 111.0000 - val_fn: 15.0000 - val_accuracy: 0.8810 - val_precision: 0.8810 - val_auc: 0.9306 - val_mae: 0.1195 - val_mse: 0.0957
Epoch 16/25
46/46 [=====] - ETA: 0s - loss: 0.1776 - tp: 1371.0000 - fp: 87.0000 - tn: 1371.0000 - fn: 87.0000 - accuracy: 0.9403 - precision: 0.9403 - auc: 0.9811 - mae: 0.0912 - mse: 0.0481
Epoch 00016: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 335ms/step - loss: 0.1776 - tp: 1371.0000 - fp: 87.0000 - tn: 1371.0000 - fn: 87.0000 - accuracy: 0.9403 - precision: 0.9403 - auc: 0.9811 - mae: 0.0912 - mse: 0.0481 - val_loss: 0.6347 - val_tp: 100.0000 - val_fp: 26.0000 - val_tn: 100.0000 - val_fn: 26.0000 - val_accuracy: 0.7937 - val_precision: 0.7937 - val_auc: 0.9126 - val_mae: 0.2084 - val_mse: 0.1734
Epoch 17/25
46/46 [=====] - ETA: 0s - loss: 0.1590 - tp: 1368.0000 - fp: 90.0000 - tn: 1368.0000 - fn: 90.0000 - accuracy: 0.9383 - precision: 0.9383 - auc: 0.9843 - mae: 0.0910 - mse: 0.0461
Epoch 00017: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 336ms/step - loss: 0.1590 - tp:

1368.0000 - fp: 90.0000 - tn: 1368.0000 - fn: 90.0000 - accuracy: 0.9383 -
precision: 0.9383 - auc: 0.9843 - mae: 0.0910 - mse: 0.0461 - val_loss: 0.1636 -
val_tp: 117.0000 - val_fp: 9.0000 - val_tn: 117.0000 - val_fn: 9.0000 -
val_accuracy: 0.9286 - val_precision: 0.9286 - val_auc: 0.9853 - val_mae: 0.0930
- val_mse: 0.0524

Epoch 18/25

46/46 [=====] - ETA: 0s - loss: 0.1658 - tp: 1362.0000
- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision:
0.9342 - auc: 0.9830 - mae: 0.0917 - mse: 0.0474

Epoch 00018: val_accuracy did not improve from 0.96825

46/46 [=====] - 15s 337ms/step - loss: 0.1658 - tp:
1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 -
precision: 0.9342 - auc: 0.9830 - mae: 0.0917 - mse: 0.0474 - val_loss: 0.5422 -
val_tp: 114.0000 - val_fp: 12.0000 - val_tn: 114.0000 - val_fn: 12.0000 -
val_accuracy: 0.9048 - val_precision: 0.9048 - val_auc: 0.9398 - val_mae: 0.1115
- val_mse: 0.0804

Epoch 19/25

46/46 [=====] - ETA: 0s - loss: 0.1508 - tp: 1376.0000
- fp: 82.0000 - tn: 1376.0000 - fn: 82.0000 - accuracy: 0.9438 - precision:
0.9438 - auc: 0.9860 - mae: 0.0810 - mse: 0.0435

Epoch 00019: val_accuracy did not improve from 0.96825

46/46 [=====] - 17s 362ms/step - loss: 0.1508 - tp:
1376.0000 - fp: 82.0000 - tn: 1376.0000 - fn: 82.0000 - accuracy: 0.9438 -
precision: 0.9438 - auc: 0.9860 - mae: 0.0810 - mse: 0.0435 - val_loss: 0.7841 -
val_tp: 112.0000 - val_fp: 14.0000 - val_tn: 112.0000 - val_fn: 14.0000 -
val_accuracy: 0.8889 - val_precision: 0.8889 - val_auc: 0.9301 - val_mae: 0.1209
- val_mse: 0.0962

Epoch 20/25

46/46 [=====] - ETA: 0s - loss: 0.1471 - tp: 1377.0000
- fp: 81.0000 - tn: 1377.0000 - fn: 81.0000 - accuracy: 0.9444 - precision:
0.9444 - auc: 0.9869 - mae: 0.0773 - mse: 0.0419

Epoch 00020: val_accuracy did not improve from 0.96825

46/46 [=====] - 16s 343ms/step - loss: 0.1471 - tp:
1377.0000 - fp: 81.0000 - tn: 1377.0000 - fn: 81.0000 - accuracy: 0.9444 -
precision: 0.9444 - auc: 0.9869 - mae: 0.0773 - mse: 0.0419 - val_loss: 0.3340 -
val_tp: 111.0000 - val_fp: 15.0000 - val_tn: 111.0000 - val_fn: 15.0000 -
val_accuracy: 0.8810 - val_precision: 0.8810 - val_auc: 0.9621 - val_mae: 0.1228
- val_mse: 0.0878

Epoch 21/25

46/46 [=====] - ETA: 0s - loss: 0.1442 - tp: 1379.0000
- fp: 79.0000 - tn: 1379.0000 - fn: 79.0000 - accuracy: 0.9458 - precision:
0.9458 - auc: 0.9870 - mae: 0.0829 - mse: 0.0428

Epoch 00021: val_accuracy did not improve from 0.96825

46/46 [=====] - 16s 337ms/step - loss: 0.1442 - tp:
1379.0000 - fp: 79.0000 - tn: 1379.0000 - fn: 79.0000 - accuracy: 0.9458 -
precision: 0.9458 - auc: 0.9870 - mae: 0.0829 - mse: 0.0428 - val_loss: 0.0775 -
val_tp: 122.0000 - val_fp: 4.0000 - val_tn: 122.0000 - val_fn: 4.0000 -
val_accuracy: 0.9683 - val_precision: 0.9683 - val_auc: 0.9977 - val_mae: 0.0588

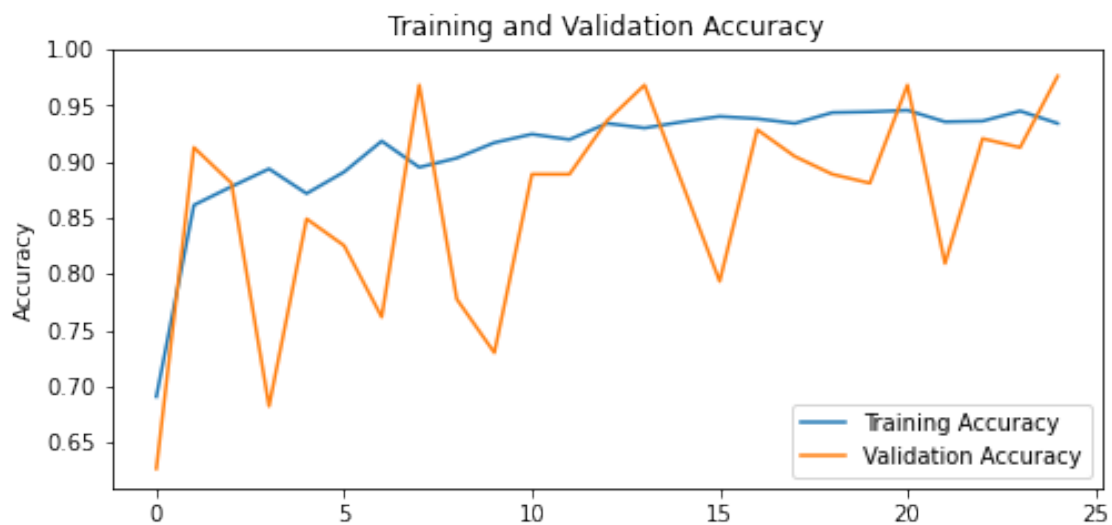

```

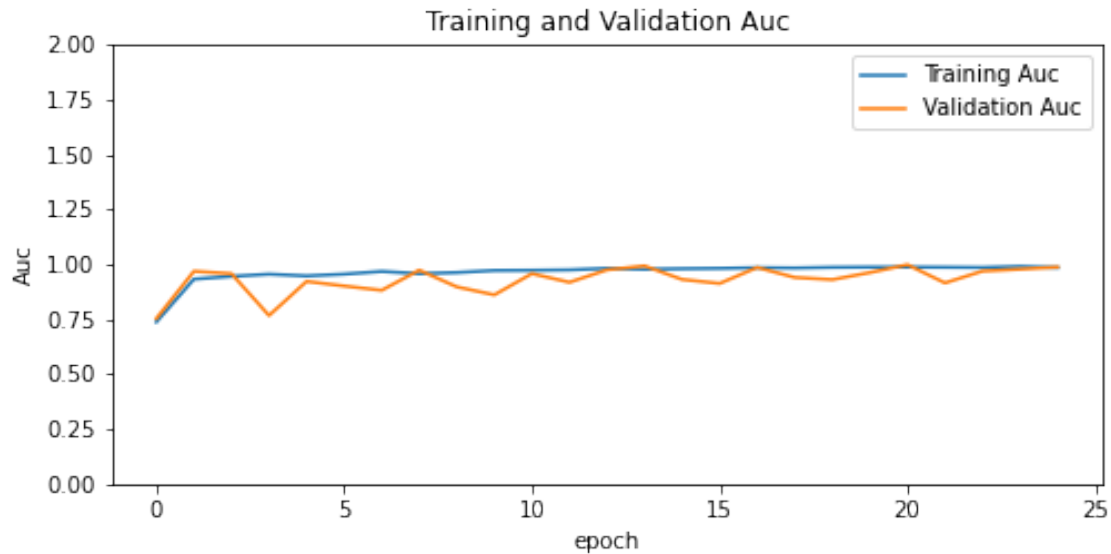
- val_mse: 0.0210
Epoch 22/25
46/46 [=====] - ETA: 0s - loss: 0.1471 - tp: 1364.0000
- fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 - precision:
0.9355 - auc: 0.9864 - mae: 0.0845 - mse: 0.0455
Epoch 00022: val_accuracy did not improve from 0.96825
46/46 [=====] - 16s 337ms/step - loss: 0.1471 - tp:
1364.0000 - fp: 94.0000 - tn: 1364.0000 - fn: 94.0000 - accuracy: 0.9355 -
precision: 0.9355 - auc: 0.9864 - mae: 0.0845 - mse: 0.0455 - val_loss: 0.5200 -
val_tp: 102.0000 - val_fp: 24.0000 - val_tn: 102.0000 - val_fn: 24.0000 -
val_accuracy: 0.8095 - val_precision: 0.8095 - val_auc: 0.9150 - val_mae: 0.1862
- val_mse: 0.1437
Epoch 23/25
46/46 [=====] - ETA: 0s - loss: 0.1539 - tp: 1365.0000
- fp: 93.0000 - tn: 1365.0000 - fn: 93.0000 - accuracy: 0.9362 - precision:
0.9362 - auc: 0.9853 - mae: 0.0858 - mse: 0.0453
Epoch 00023: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 337ms/step - loss: 0.1539 - tp:
1365.0000 - fp: 93.0000 - tn: 1365.0000 - fn: 93.0000 - accuracy: 0.9362 -
precision: 0.9362 - auc: 0.9853 - mae: 0.0858 - mse: 0.0453 - val_loss: 0.3217 -
val_tp: 116.0000 - val_fp: 10.0000 - val_tn: 116.0000 - val_fn: 10.0000 -
val_accuracy: 0.9206 - val_precision: 0.9206 - val_auc: 0.9689 - val_mae: 0.1054
- val_mse: 0.0654
Epoch 24/25
46/46 [=====] - ETA: 0s - loss: 0.1279 - tp: 1378.0000
- fp: 80.0000 - tn: 1378.0000 - fn: 80.0000 - accuracy: 0.9451 - precision:
0.9451 - auc: 0.9898 - mae: 0.0763 - mse: 0.0383
Epoch 00024: val_accuracy did not improve from 0.96825
46/46 [=====] - 15s 335ms/step - loss: 0.1279 - tp:
1378.0000 - fp: 80.0000 - tn: 1378.0000 - fn: 80.0000 - accuracy: 0.9451 -
precision: 0.9451 - auc: 0.9898 - mae: 0.0763 - mse: 0.0383 - val_loss: 0.1965 -
val_tp: 115.0000 - val_fp: 11.0000 - val_tn: 115.0000 - val_fn: 11.0000 -
val_accuracy: 0.9127 - val_precision: 0.9127 - val_auc: 0.9775 - val_mae: 0.1083
- val_mse: 0.0666
Epoch 25/25
46/46 [=====] - ETA: 0s - loss: 0.1621 - tp: 1362.0000
- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision:
0.9342 - auc: 0.9845 - mae: 0.0839 - mse: 0.0479
Epoch 00025: val_accuracy improved from 0.96825 to 0.97619, saving model to
./models\Model_3.hdf5
46/46 [=====] - 15s 335ms/step - loss: 0.1621 - tp:
1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 -
precision: 0.9342 - auc: 0.9845 - mae: 0.0839 - mse: 0.0479 - val_loss: 0.1187 -
val_tp: 123.0000 - val_fp: 3.0000 - val_tn: 123.0000 - val_fn: 3.0000 -
val_accuracy: 0.9762 - val_precision: 0.9762 - val_auc: 0.9870 - val_mae: 0.0370
- val_mse: 0.0231

```

1.1.16 6. Display History 3

```
[25]: print_history(history3)
```





1.1.17 7. Evaluate the model 3

```
[26]: print_model_evaluation(model3);
```

```
714/714 [=====] - 3s 4ms/step - loss: 0.4579 - tp:
666.0000 - fp: 48.0000 - tn: 666.0000 - fn: 48.0000 - accuracy: 0.9328 -
precision: 0.9328 - auc: 0.9721 - mae: 0.0834 - mse: 0.0561
loss : 0.458
tp : 666.0
fp : 48.0
tn : 666.0
fn : 48.0
accuracy : 0.933
precision : 0.933
auc : 0.972
mae : 0.083
mse : 0.056
```

1.1.18 8. Predict with model 3

```
[27]: predict_and_print_roc(model3);
```

Label Predictions:

```
[0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0,
0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0,
0, 1, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 1, 0, 0,
1, 1, 1, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0,
1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1]
```

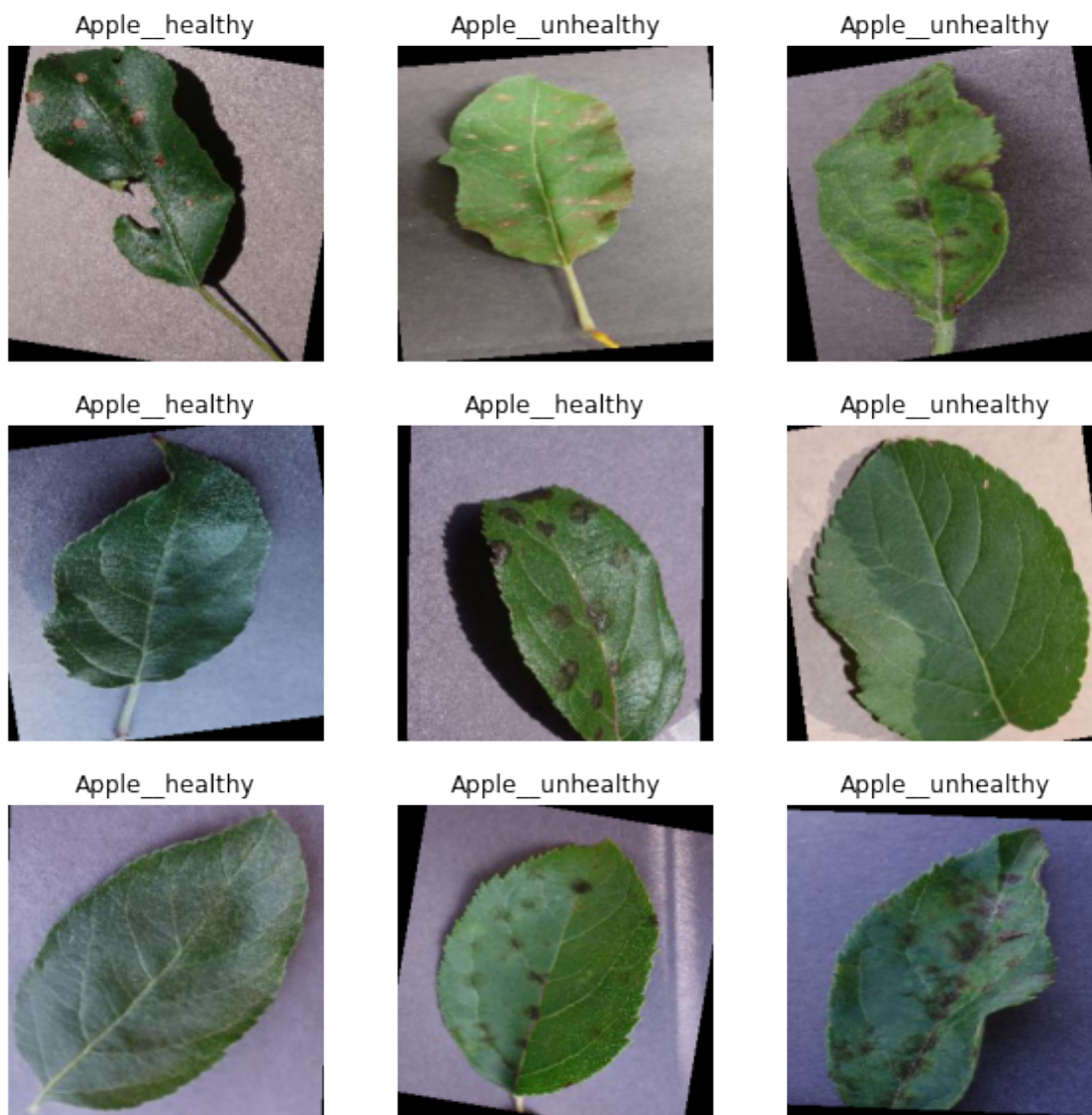
Real Labels:

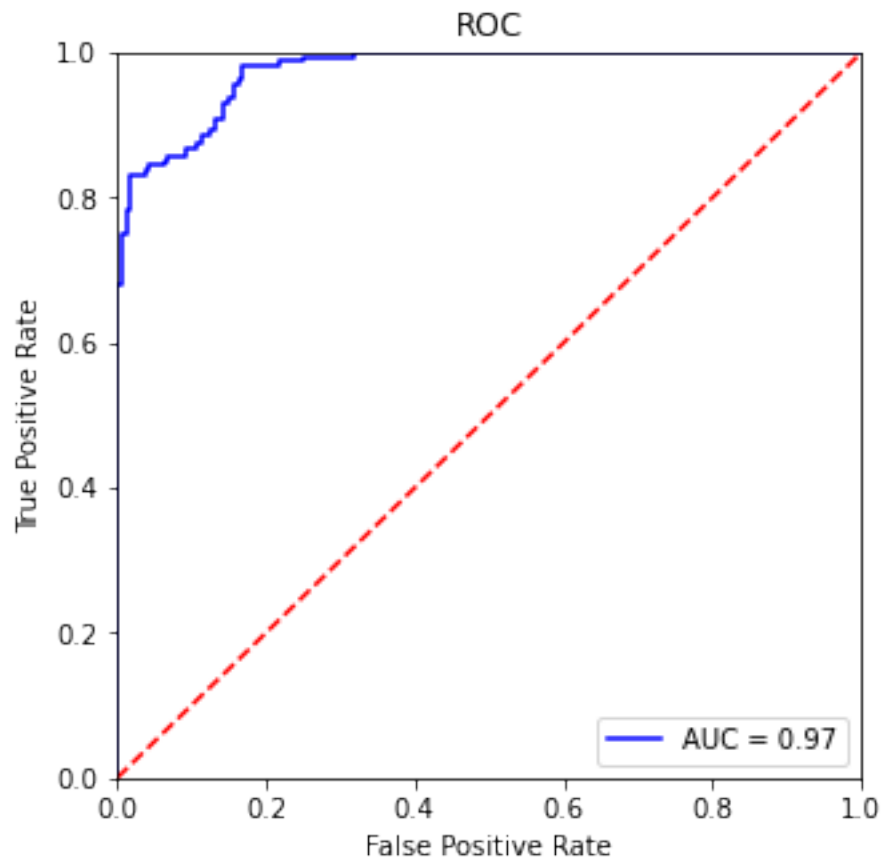
```
[1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 1, 1, 0,
0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 0, 0,
0, 1, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0,
1, 1, 0, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0,
0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0,
1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1]
```

Confusion Matrix:

```
[[73  6]
 [12 69]]
```

Accuracy: 0.89





1.1.19 9. Save test model

```
[32]: model3.save(MODEL_NAME)
```

1.1.20 10. Load test model

```
[33]: loaded_model = tf.keras.models.load_model(MODEL_NAME)
```

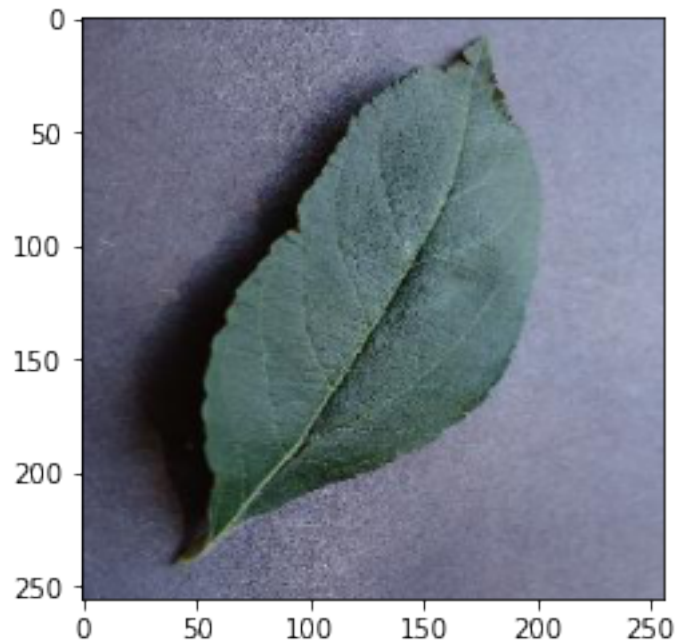
1.1.21 11. Test loaded model on image:

```
[34]: healthyTestImagePath = "./plant_images/test/Apple_healthy/  
    ↳2d7f4c07-f4f4-4589-aa82-49e05e5b253b__RS_HL 8056.jpg"  
  
healthyTestImage = image.load_img(healthyTestImagePath)  
plt.imshow(healthyTestImage)  
healthyTestImage = (np.expand_dims(healthyTestImage,0))  
predictions = loaded_model.predict(healthyTestImage)
```

```
print('Expected result: [1, 0] \n')
print('Result: ', predictions, '\n')
```

Expected result: [1, 0]

Result: [[1. 0.]]

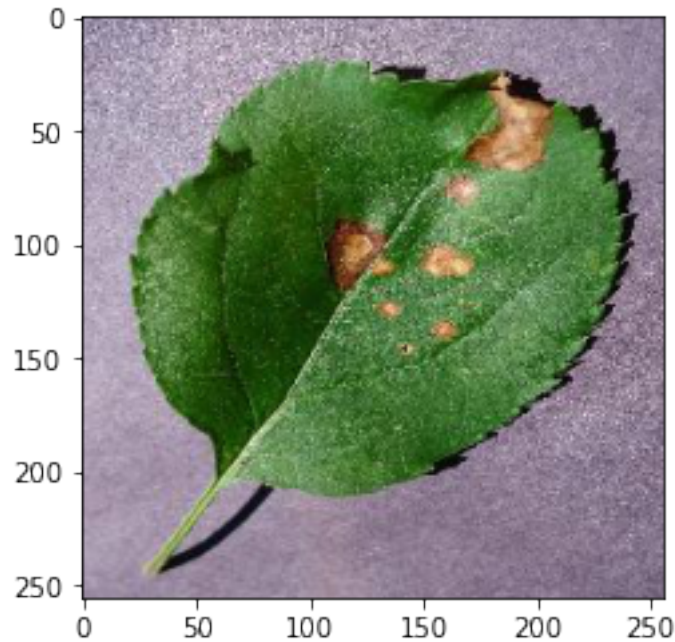


```
[35]: unhealthyTestImagePath = "./plant_images/test/Apple__unhealthy/
      ↪0ebea6f4-08e4-4380-86f8-34d854697e32__JR_FrgE.S 2877.jpg"
unhealthyTestImage = image.load_img(unhealthyTestImagePath)
plt.imshow(unhealthyTestImage)
unhealthyTestImage = (np.expand_dims(unhealthyTestImage,0))
predictions = loaded_model.predict(unhealthyTestImage)

print('Expected result: [0, 1] \n')
print('Result: ', predictions, '\n')
```

Expected result: [0, 1]

Result: [[0. 1.]]



1.2 Summary

- All the models were trained with 25 epochs. The reason for this is that after this amount the results were sufficient for comparison and overfitting could be avoided (tested with 50 epochs before). Model training is also very expensive which makes it harder to refine the models.
- The batch normalization in each model was necessary to create stable runs. Without it, the training of the model converged to a loss of 0.5 at some runs. Without the batch normalization model 2 and 3 had better results, which however were quite unstable.
- Models with more than three convolution layers did not improve the models at all and were therefore not added to the final test models.

1.2.1 Model 1:

This is a very simple model that worked the very well. Showing that a small amount of layers can already create a very good model.

1.2.2 Model 2:

Has more hidden and dense layers than model 1. Increasing the number of neurons in each layer, however, didn't seem to work as well as expected. Surprisingly, the result is even worse than model one, which uses a lot fewer layers. Based on the parameter it even has the same amount than model 1.

1.2.3 Model 3:

This model seems to perform just as good as model 1, based on the false positive and false negative validation. Decreasing the size of the image and the neurons and leaving the amount of layers

around 2-3 seemed however to work best for this image recognition.

1.3 Additional Experiments

Out of curiosity we've also recreated the same model in ML.NET integrated in an .NET Core Web Application. See additional document.

[]: