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')
```

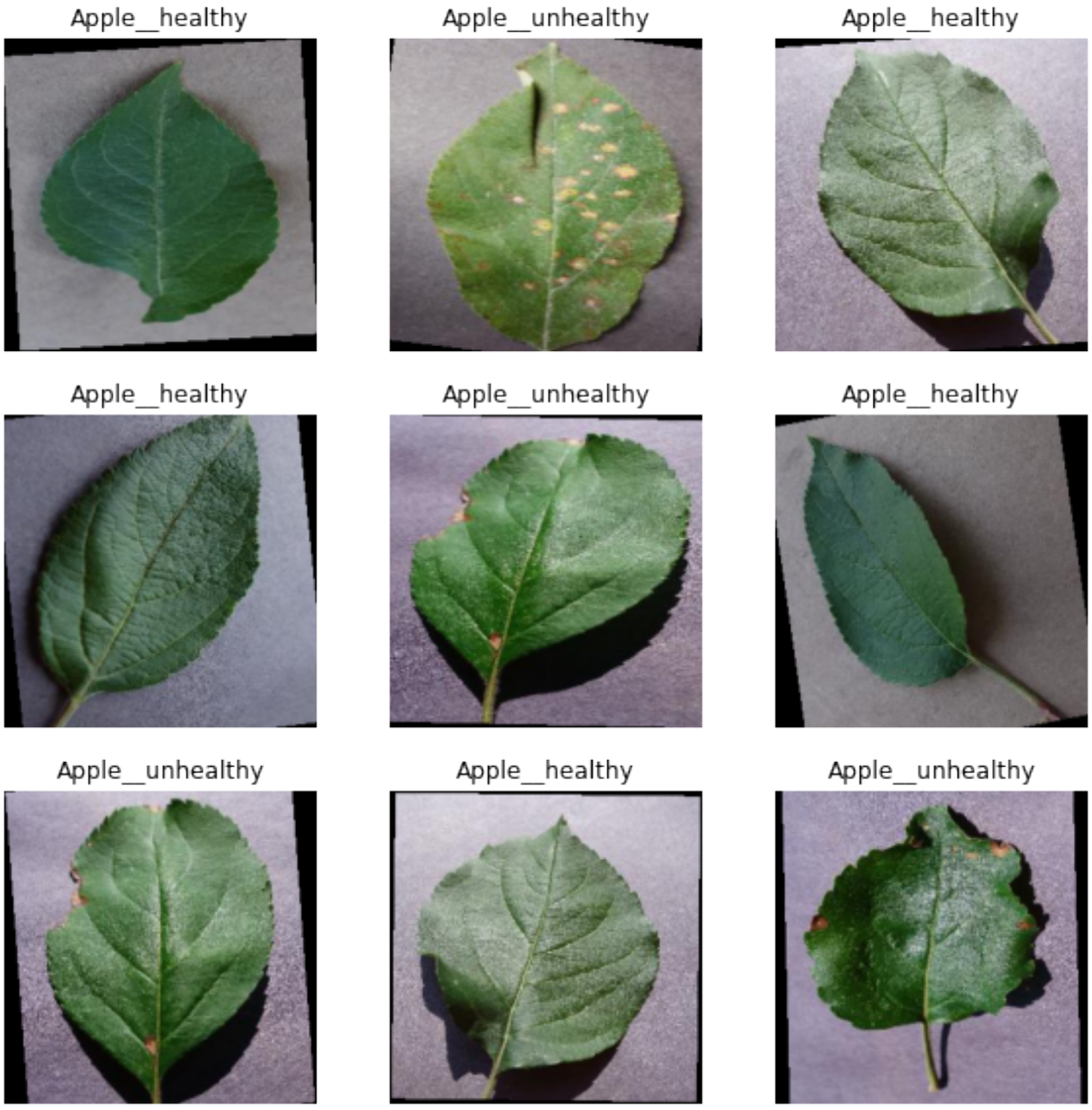
```
Found 1458 images belonging to 2 classes.
Found 126 images belonging to 2 classes.
Found 714 images belonging to 2 classes.
```

[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, categoriacal 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.Flatten(),
    tf.keras.layers.BatchNormalization(),
    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)
```

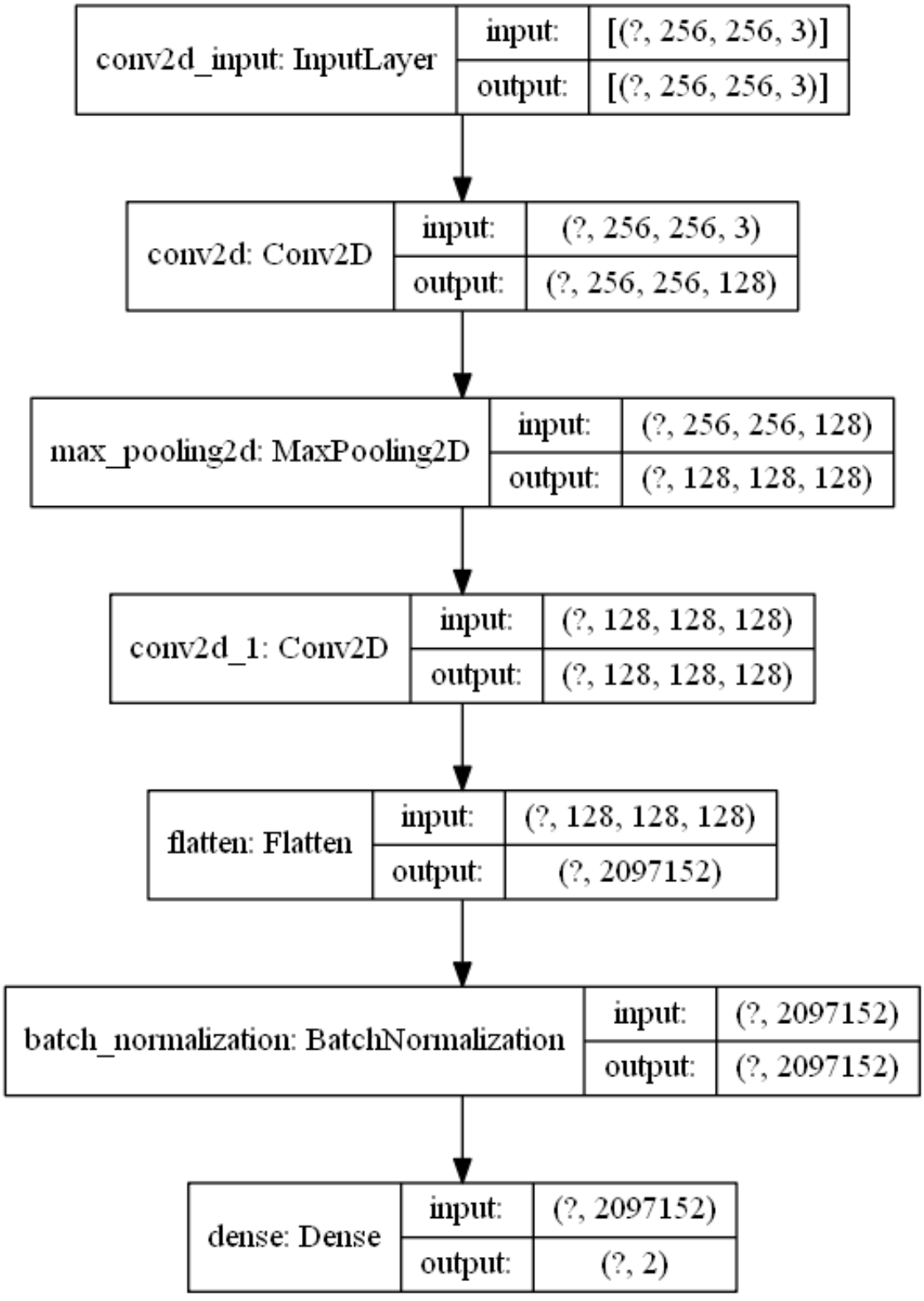
1.1.2 4. Display model structure 1

[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
_________________________________________________________________
flatten (Flatten)            (None, 2097152)           0
_________________________________________________________________
batch_normalization (BatchNo (None, 2097152)           8388608
_________________________________________________________________
dense (Dense)                (None, 2)                 4194306
=================================================================
Total params: 12,733,826
Trainable params: 8,539,522
Non-trainable params: 4,194,304
_________________________________________________________________
```

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

[9]:


conv2d_input: InputLayer
input: [(?, 256, 256, 3)]
output: [(?, 256, 256, 3)]
conv2d: Conv2D
input: (?, 256, 256, 3)
output: (?, 256, 256, 128)
max_pooling2d: MaxPooling2D
input: (?, 256, 256, 128)
output: (?, 128, 128, 128)
conv2d_1: Conv2D
input: (?, 128, 128, 128)
output: (?, 128, 128, 128)
flatten: Flatten
input: (?, 128, 128, 128)
output: (?, 2097152)
batch_normalization: BatchNormalization
input: (?, 2097152)
output: (?, 2097152)
dense: Dense
input: (?, 2097152)
output: (?, 2)

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,
                                                    save_best_only=True,␣
 ↪mode='max')
    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: 4.6963 - tp: 1061.0000
- fp: 397.0000 - tn: 1061.0000 - fn: 397.0000 - accuracy: 0.7277 - precision:
0.7277 - auc: 0.8032 - mae: 0.2749 - mse: 0.2373
Epoch 00001: val_accuracy improved from -inf to 0.51587, saving model to
./models\Model_1.hdf5
46/46 [==============================] - 17s 361ms/step - loss: 4.6963 - tp:
1061.0000 - fp: 397.0000 - tn: 1061.0000 - fn: 397.0000 - accuracy: 0.7277 -
precision: 0.7277 - auc: 0.8032 - mae: 0.2749 - mse: 0.2373 - val_loss: 1.5272 -
val_tp: 65.0000 - val_fp: 61.0000 - val_tn: 65.0000 - val_fn: 61.0000 -
val_accuracy: 0.5159 - val_precision: 0.5159 - val_auc: 0.5574 - val_mae: 0.4847
- val_mse: 0.4426
Epoch 2/25
46/46 [==============================] - ETA: 0s - loss: 1.2537 - tp: 1042.0000
- fp: 416.0000 - tn: 1042.0000 - fn: 416.0000 - accuracy: 0.7147 - precision:
0.7147 - auc: 0.7979 - mae: 0.2898 - mse: 0.2444
Epoch 00002: val_accuracy did not improve from 0.51587
46/46 [==============================] - 16s 337ms/step - loss: 1.2537 - tp:
1042.0000 - fp: 416.0000 - tn: 1042.0000 - fn: 416.0000 - accuracy: 0.7147 -
precision: 0.7147 - auc: 0.7979 - mae: 0.2898 - mse: 0.2444 - val_loss: 0.9223 -
val_tp: 65.0000 - val_fp: 61.0000 - val_tn: 65.0000 - val_fn: 61.0000 -
val_accuracy: 0.5159 - val_precision: 0.5159 - val_auc: 0.7312 - val_mae: 0.4495
- val_mse: 0.3355
Epoch 3/25
46/46 [==============================] - ETA: 0s - loss: 0.7446 - tp: 1034.0000
- fp: 424.0000 - tn: 1034.0000 - fn: 424.0000 - accuracy: 0.7092 - precision:
0.7092 - auc: 0.8063 - mae: 0.3016 - mse: 0.1995
Epoch 00003: val_accuracy did not improve from 0.51587
46/46 [==============================] - 16s 337ms/step - loss: 0.7446 - tp:
1034.0000 - fp: 424.0000 - tn: 1034.0000 - fn: 424.0000 - accuracy: 0.7092 -
```

```
precision: 0.7092 - auc: 0.8063 - mae: 0.3016 - mse: 0.1995 - val_loss: 1.0137 -
val_tp: 65.0000 - val_fp: 61.0000 - val_tn: 65.0000 - val_fn: 61.0000 -
val_accuracy: 0.5159 - val_precision: 0.5159 - val_auc: 0.5532 - val_mae: 0.4884
- val_mse: 0.3643
Epoch 4/25
46/46 [==============================] - ETA: 0s - loss: 0.7685 - tp: 831.0000 -
fp: 627.0000 - tn: 831.0000 - fn: 627.0000 - accuracy: 0.5700 - precision:
0.5700 - auc: 0.6122 - mae: 0.4445 - mse: 0.2666
Epoch 00004: val_accuracy did not improve from 0.51587
46/46 [==============================] - 15s 337ms/step - loss: 0.7685 - tp:
831.0000 - fp: 627.0000 - tn: 831.0000 - fn: 627.0000 - accuracy: 0.5700 -
precision: 0.5700 - auc: 0.6122 - mae: 0.4445 - mse: 0.2666 - val_loss: 1.3093 -
val_tp: 65.0000 - val_fp: 61.0000 - val_tn: 65.0000 - val_fn: 61.0000 -
val_accuracy: 0.5159 - val_precision: 0.5159 - val_auc: 0.6339 - val_mae: 0.4816
- val_mse: 0.4178
Epoch 5/25
46/46 [==============================] - ETA: 0s - loss: 0.8426 - tp: 926.0000 -
fp: 532.0000 - tn: 926.0000 - fn: 532.0000 - accuracy: 0.6351 - precision:
0.6351 - auc: 0.6911 - mae: 0.3892 - mse: 0.2616
Epoch 00005: val_accuracy did not improve from 0.51587
46/46 [==============================] - 16s 338ms/step - loss: 0.8426 - tp:
926.0000 - fp: 532.0000 - tn: 926.0000 - fn: 532.0000 - accuracy: 0.6351 -
precision: 0.6351 - auc: 0.6911 - mae: 0.3892 - mse: 0.2616 - val_loss: 0.8998 -
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: 0.6973 - val_mae: 0.4647
- val_mse: 0.3402
Epoch 6/25
46/46 [==============================] - ETA: 0s - loss: 0.6174 - tp: 1141.0000
- fp: 317.0000 - tn: 1141.0000 - fn: 317.0000 - accuracy: 0.7826 - precision:
0.7826 - auc: 0.8634 - mae: 0.2428 - mse: 0.1610
Epoch 00006: val_accuracy did not improve from 0.51587
46/46 [==============================] - 16s 338ms/step - loss: 0.6174 - tp:
1141.0000 - fp: 317.0000 - tn: 1141.0000 - fn: 317.0000 - accuracy: 0.7826 -
precision: 0.7826 - auc: 0.8634 - mae: 0.2428 - mse: 0.1610 - val_loss: 1.3110 -
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: 0.7105 - val_mae: 0.4822
- val_mse: 0.4309
Epoch 7/25
46/46 [==============================] - ETA: 0s - loss: 0.5863 - tp: 1198.0000
- fp: 260.0000 - tn: 1198.0000 - fn: 260.0000 - accuracy: 0.8217 - precision:
0.8217 - auc: 0.9008 - mae: 0.1958 - mse: 0.1358
Epoch 00007: val_accuracy improved from 0.51587 to 0.90476, saving model to
./models\Model_1.hdf5
46/46 [==============================] - 16s 348ms/step - loss: 0.5863 - tp:
1198.0000 - fp: 260.0000 - tn: 1198.0000 - fn: 260.0000 - accuracy: 0.8217 -
precision: 0.8217 - auc: 0.9008 - mae: 0.1958 - mse: 0.1358 - val_loss: 0.2946 -
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: 0.9567 - val_mae: 0.2144
```

```
- val_mse: 0.0857
Epoch 8/25
46/46 [==============================] - ETA: 0s - loss: 0.9406 - tp: 1168.0000
- fp: 290.0000 - tn: 1168.0000 - fn: 290.0000 - accuracy: 0.8011 - precision:
0.8011 - auc: 0.8570 - mae: 0.2134 - mse: 0.1727
Epoch 00008: val_accuracy did not improve from 0.90476
46/46 [==============================] - 16s 341ms/step - loss: 0.9406 - tp:
1168.0000 - fp: 290.0000 - tn: 1168.0000 - fn: 290.0000 - accuracy: 0.8011 -
precision: 0.8011 - auc: 0.8570 - mae: 0.2134 - mse: 0.1727 - val_loss: 0.8650 -
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: 0.6815 - val_mae: 0.4662
- val_mse: 0.3285
Epoch 9/25
46/46 [==============================] - ETA: 0s - loss: 0.4287 - tp: 1248.0000
- fp: 210.0000 - tn: 1248.0000 - fn: 210.0000 - accuracy: 0.8560 - precision:
0.8560 - auc: 0.9252 - mae: 0.1650 - mse: 0.1088
Epoch 00009: val_accuracy did not improve from 0.90476
46/46 [==============================] - 16s 340ms/step - loss: 0.4287 - tp:
1248.0000 - fp: 210.0000 - tn: 1248.0000 - fn: 210.0000 - accuracy: 0.8560 -
precision: 0.8560 - auc: 0.9252 - mae: 0.1650 - mse: 0.1088 - val_loss: 0.3418 -
val_tp: 109.0000 - val_fp: 17.0000 - val_tn: 109.0000 - val_fn: 17.0000 -
val_accuracy: 0.8651 - val_precision: 0.8651 - val_auc: 0.9431 - val_mae: 0.2519
- val_mse: 0.1022
Epoch 10/25
46/46 [==============================] - ETA: 0s - loss: 0.4085 - tp: 1238.0000
- fp: 220.0000 - tn: 1238.0000 - fn: 220.0000 - accuracy: 0.8491 - precision:
0.8491 - auc: 0.9223 - mae: 0.1775 - mse: 0.1104
Epoch 00010: val_accuracy did not improve from 0.90476
46/46 [==============================] - 16s 341ms/step - loss: 0.4085 - tp:
1238.0000 - fp: 220.0000 - tn: 1238.0000 - fn: 220.0000 - accuracy: 0.8491 -
precision: 0.8491 - auc: 0.9223 - mae: 0.1775 - mse: 0.1104 - val_loss: 0.5447 -
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: 0.7889 - val_mae: 0.3351
- val_mse: 0.1969
Epoch 11/25
46/46 [==============================] - ETA: 0s - loss: 0.6555 - tp: 1191.0000
- fp: 267.0000 - tn: 1191.0000 - fn: 267.0000 - accuracy: 0.8169 - precision:
0.8169 - auc: 0.8910 - mae: 0.1916 - mse: 0.1441
Epoch 00011: val_accuracy did not improve from 0.90476
46/46 [==============================] - 16s 337ms/step - loss: 0.6555 - tp:
1191.0000 - fp: 267.0000 - tn: 1191.0000 - fn: 267.0000 - accuracy: 0.8169 -
precision: 0.8169 - auc: 0.8910 - mae: 0.1916 - mse: 0.1441 - val_loss: 0.3425 -
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: 0.9270 - val_mae: 0.2277
- val_mse: 0.1087
Epoch 12/25
46/46 [==============================] - ETA: 0s - loss: 0.3554 - tp: 1268.0000
- fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 - precision:
```

```
0.8697 - auc: 0.9363 - mae: 0.1647 - mse: 0.1001
Epoch 00012: val_accuracy did not improve from 0.90476
46/46 [==============================] - 16s 339ms/step - loss: 0.3554 - tp:
1268.0000 - fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 -
precision: 0.8697 - auc: 0.9363 - mae: 0.1647 - mse: 0.1001 - val_loss: 0.2391 -
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: 0.9665 - val_mae: 0.1569
- val_mse: 0.0707
Epoch 13/25
46/46 [==============================] - ETA: 0s - loss: 0.4982 - tp: 1205.0000
- fp: 253.0000 - tn: 1205.0000 - fn: 253.0000 - accuracy: 0.8265 - precision:
0.8265 - auc: 0.9081 - mae: 0.1906 - mse: 0.1305
Epoch 00013: val_accuracy did not improve from 0.90476
46/46 [==============================] - 15s 337ms/step - loss: 0.4982 - tp:
1205.0000 - fp: 253.0000 - tn: 1205.0000 - fn: 253.0000 - accuracy: 0.8265 -
precision: 0.8265 - auc: 0.9081 - mae: 0.1906 - mse: 0.1305 - val_loss: 0.3634 -
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: 0.9226 - val_mae: 0.2059
- val_mse: 0.1090
Epoch 14/25
46/46 [==============================] - ETA: 0s - loss: 0.3710 - tp: 1236.0000
- fp: 222.0000 - tn: 1236.0000 - fn: 222.0000 - accuracy: 0.8477 - precision:
0.8477 - auc: 0.9320 - mae: 0.1731 - mse: 0.1095
Epoch 00014: val_accuracy improved from 0.90476 to 0.92063, saving model to
./models\Model_1.hdf5
46/46 [==============================] - 16s 339ms/step - loss: 0.3710 - tp:
1236.0000 - fp: 222.0000 - tn: 1236.0000 - fn: 222.0000 - accuracy: 0.8477 -
precision: 0.8477 - auc: 0.9320 - mae: 0.1731 - mse: 0.1095 - val_loss: 0.2543 -
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: 0.9623 - val_mae: 0.1146
- val_mse: 0.0684
Epoch 15/25
46/46 [==============================] - ETA: 0s - loss: 0.2881 - tp: 1299.0000
- fp: 159.0000 - tn: 1299.0000 - fn: 159.0000 - accuracy: 0.8909 - precision:
0.8909 - auc: 0.9552 - mae: 0.1365 - mse: 0.0813
Epoch 00015: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 358ms/step - loss: 0.2881 - tp:
1299.0000 - fp: 159.0000 - tn: 1299.0000 - fn: 159.0000 - accuracy: 0.8909 -
precision: 0.8909 - auc: 0.9552 - mae: 0.1365 - mse: 0.0813 - val_loss: 0.4004 -
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: 0.9109 - val_mae: 0.2161
- val_mse: 0.1205
Epoch 16/25
46/46 [==============================] - ETA: 0s - loss: 0.4167 - tp: 1246.0000
- fp: 212.0000 - tn: 1246.0000 - fn: 212.0000 - accuracy: 0.8546 - precision:
0.8546 - auc: 0.9258 - mae: 0.1723 - mse: 0.1102
Epoch 00016: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 358ms/step - loss: 0.4167 - tp:
```

```
1246.0000 - fp: 212.0000 - tn: 1246.0000 - fn: 212.0000 - accuracy: 0.8546 -
precision: 0.8546 - auc: 0.9258 - mae: 0.1723 - mse: 0.1102 - val_loss: 1.3995 -
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: 0.7663 - val_mae: 0.3181
- val_mse: 0.2769
Epoch 17/25
46/46 [==============================] - ETA: 0s - loss: 0.4421 - tp: 1228.0000
- fp: 230.0000 - tn: 1228.0000 - fn: 230.0000 - accuracy: 0.8422 - precision:
0.8422 - auc: 0.9169 - mae: 0.1854 - mse: 0.1191
Epoch 00017: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 343ms/step - loss: 0.4421 - tp:
1228.0000 - fp: 230.0000 - tn: 1228.0000 - fn: 230.0000 - accuracy: 0.8422 -
precision: 0.8422 - auc: 0.9169 - mae: 0.1854 - mse: 0.1191 - val_loss: 0.3081 -
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: 0.9531 - val_mae: 0.1263
- val_mse: 0.0827
Epoch 18/25
46/46 [==============================] - ETA: 0s - loss: 0.3766 - tp: 1266.0000
- fp: 192.0000 - tn: 1266.0000 - fn: 192.0000 - accuracy: 0.8683 - precision:
0.8683 - auc: 0.9364 - mae: 0.1574 - mse: 0.1022
Epoch 00018: val_accuracy improved from 0.92063 to 0.92857, saving model to
./models\Model_1.hdf5
46/46 [==============================] - 17s 373ms/step - loss: 0.3766 - tp:
1266.0000 - fp: 192.0000 - tn: 1266.0000 - fn: 192.0000 - accuracy: 0.8683 -
precision: 0.8683 - auc: 0.9364 - mae: 0.1574 - mse: 0.1022 - val_loss: 0.1892 -
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: 0.9806 - val_mae: 0.1384
- val_mse: 0.0577
Epoch 19/25
46/46 [==============================] - ETA: 0s - loss: 0.3571 - tp: 1262.0000
- fp: 196.0000 - tn: 1262.0000 - fn: 196.0000 - accuracy: 0.8656 - precision:
0.8656 - auc: 0.9378 - mae: 0.1633 - mse: 0.1013
Epoch 00019: val_accuracy did not improve from 0.92857
46/46 [==============================] - 16s 343ms/step - loss: 0.3571 - tp:
1262.0000 - fp: 196.0000 - tn: 1262.0000 - fn: 196.0000 - accuracy: 0.8656 -
precision: 0.8656 - auc: 0.9378 - mae: 0.1633 - mse: 0.1013 - val_loss: 0.3577 -
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: 0.9515 - val_mae: 0.1127
- val_mse: 0.0781
Epoch 20/25
46/46 [==============================] - ETA: 0s - loss: 0.3309 - tp: 1256.0000
- fp: 202.0000 - tn: 1256.0000 - fn: 202.0000 - accuracy: 0.8615 - precision:
0.8615 - auc: 0.9428 - mae: 0.1611 - mse: 0.0983
Epoch 00020: val_accuracy did not improve from 0.92857
46/46 [==============================] - 16s 339ms/step - loss: 0.3309 - tp:
1256.0000 - fp: 202.0000 - tn: 1256.0000 - fn: 202.0000 - accuracy: 0.8615 -
precision: 0.8615 - auc: 0.9428 - mae: 0.1611 - mse: 0.0983 - val_loss: 0.3114 -
val_tp: 115.0000 - val_fp: 11.0000 - val_tn: 115.0000 - val_fn: 11.0000 -
```

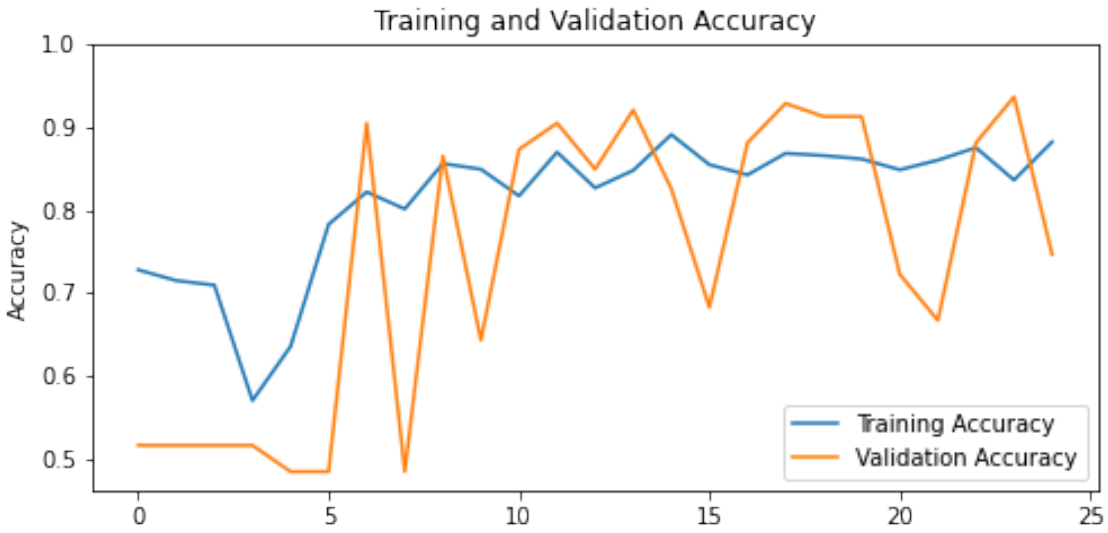
```
val_accuracy: 0.9127 - val_precision: 0.9127 - val_auc: 0.9600 - val_mae: 0.1072
- val_mse: 0.0724
Epoch 21/25
46/46 [==============================] - ETA: 0s - loss: 0.4461 - tp: 1237.0000
- fp: 221.0000 - tn: 1237.0000 - fn: 221.0000 - accuracy: 0.8484 - precision:
0.8484 - auc: 0.9218 - mae: 0.1724 - mse: 0.1158
Epoch 00021: val_accuracy did not improve from 0.92857
46/46 [==============================] - 16s 337ms/step - loss: 0.4461 - tp:
1237.0000 - fp: 221.0000 - tn: 1237.0000 - fn: 221.0000 - accuracy: 0.8484 -
precision: 0.8484 - auc: 0.9218 - mae: 0.1724 - mse: 0.1158 - val_loss: 0.7716 -
val_tp: 91.0000 - val_fp: 35.0000 - val_tn: 91.0000 - val_fn: 35.0000 -
val_accuracy: 0.7222 - val_precision: 0.7222 - val_auc: 0.8168 - val_mae: 0.3000
- val_mse: 0.2218
Epoch 22/25
46/46 [==============================] - ETA: 0s - loss: 0.4213 - tp: 1254.0000
- fp: 204.0000 - tn: 1254.0000 - fn: 204.0000 - accuracy: 0.8601 - precision:
0.8601 - auc: 0.9352 - mae: 0.1564 - mse: 0.1075
Epoch 00022: val_accuracy did not improve from 0.92857
46/46 [==============================] - 15s 337ms/step - loss: 0.4213 - tp:
1254.0000 - fp: 204.0000 - tn: 1254.0000 - fn: 204.0000 - accuracy: 0.8601 -
precision: 0.8601 - auc: 0.9352 - mae: 0.1564 - mse: 0.1075 - val_loss: 1.5127 -
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: 0.7779 - val_mae: 0.3263
- val_mse: 0.2983
Epoch 23/25
46/46 [==============================] - ETA: 0s - loss: 0.3644 - tp: 1276.0000
- fp: 182.0000 - tn: 1276.0000 - fn: 182.0000 - accuracy: 0.8752 - precision:
0.8752 - auc: 0.9393 - mae: 0.1532 - mse: 0.0987
Epoch 00023: val_accuracy did not improve from 0.92857
46/46 [==============================] - 16s 343ms/step - loss: 0.3644 - tp:
1276.0000 - fp: 182.0000 - tn: 1276.0000 - fn: 182.0000 - accuracy: 0.8752 -
precision: 0.8752 - auc: 0.9393 - mae: 0.1532 - mse: 0.0987 - val_loss: 0.3790 -
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: 0.9536 - val_mae: 0.1226
- val_mse: 0.0948
Epoch 24/25
46/46 [==============================] - ETA: 0s - loss: 0.5371 - tp: 1219.0000
- fp: 239.0000 - tn: 1219.0000 - fn: 239.0000 - accuracy: 0.8361 - precision:
0.8361 - auc: 0.9122 - mae: 0.1782 - mse: 0.1253
Epoch 00024: val_accuracy improved from 0.92857 to 0.93651, saving model to
./models\Model_1.hdf5
46/46 [==============================] - 16s 340ms/step - loss: 0.5371 - tp:
1219.0000 - fp: 239.0000 - tn: 1219.0000 - fn: 239.0000 - accuracy: 0.8361 -
precision: 0.8361 - auc: 0.9122 - mae: 0.1782 - mse: 0.1253 - val_loss: 0.3172 -
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: 0.9615 - val_mae: 0.0830
- val_mse: 0.0586
Epoch 25/25
```

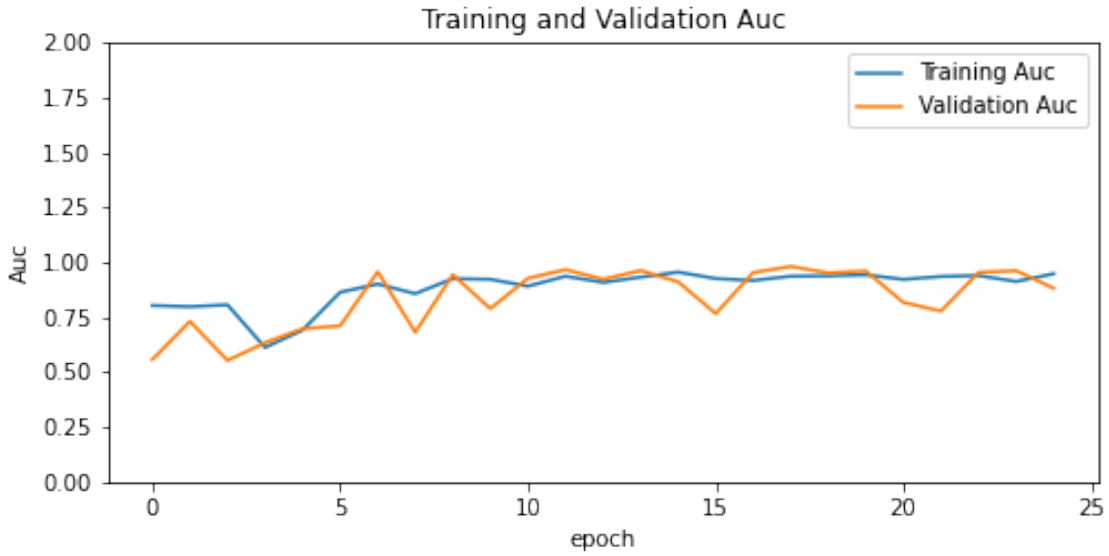
```
46/46 [==============================] - ETA: 0s - loss: 0.3251 - tp: 1286.0000
- fp: 172.0000 - tn: 1286.0000 - fn: 172.0000 - accuracy: 0.8820 - precision:
0.8820 - auc: 0.9474 - mae: 0.1491 - mse: 0.0902
Epoch 00025: val_accuracy did not improve from 0.93651
46/46 [==============================] - 15s 336ms/step - loss: 0.3251 - tp:
1286.0000 - fp: 172.0000 - tn: 1286.0000 - fn: 172.0000 - accuracy: 0.8820 -
precision: 0.8820 - auc: 0.9474 - mae: 0.1491 - mse: 0.0902 - val_loss: 0.5859 -
val_tp: 94.0000 - val_fp: 32.0000 - val_tn: 94.0000 - val_fn: 32.0000 -
val_accuracy: 0.7460 - val_precision: 0.7460 - val_auc: 0.8817 - val_mae: 0.2471
- val_mse: 0.1856
```

1.1.4 6. Write history and plot graphs 1

[11]:
```python
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);
```

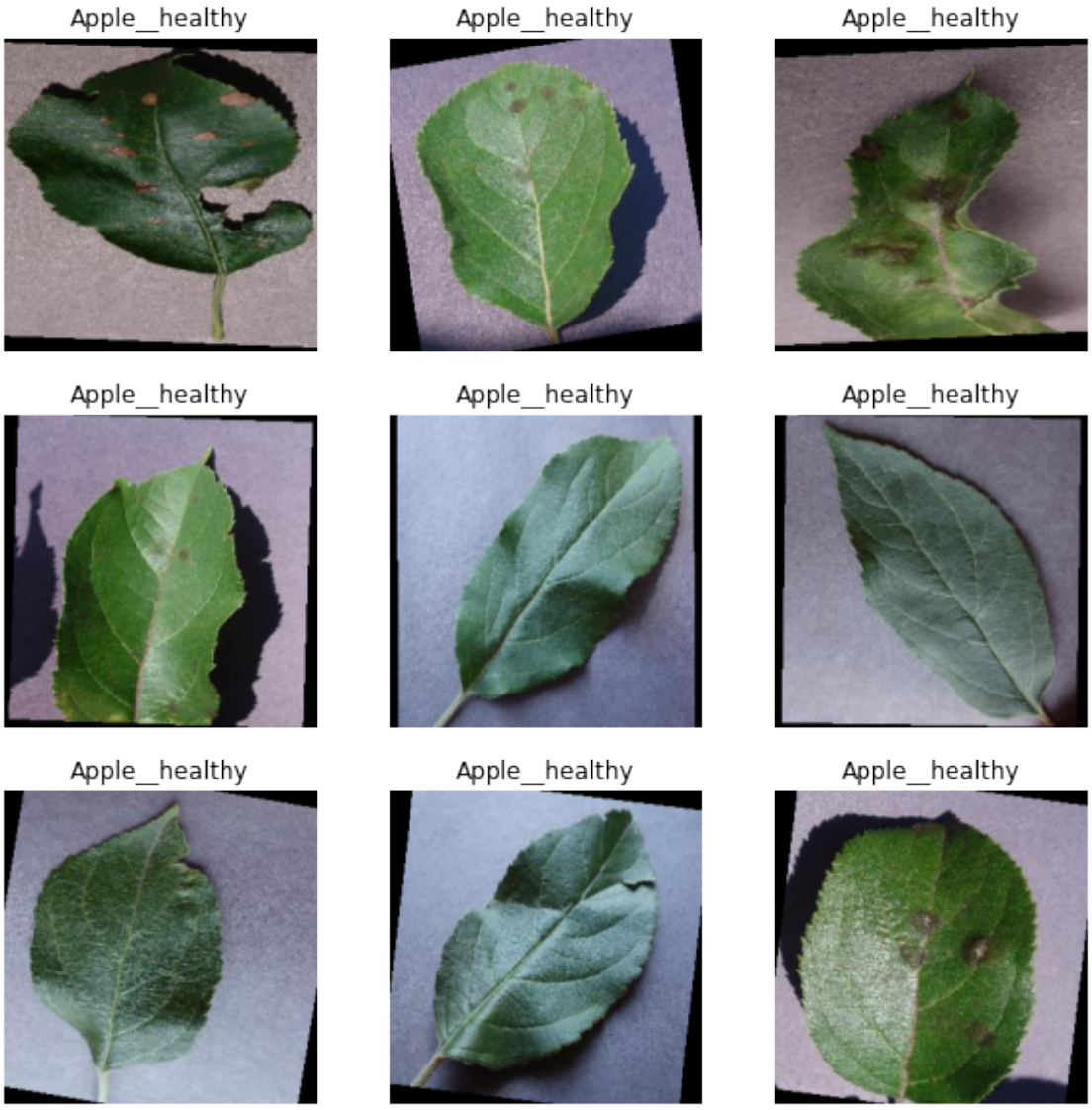
```
714/714 [==============================] - 4s 5ms/step - loss: 0.6744 - tp:
540.0000 - fp: 174.0000 - tn: 540.0000 - fn: 174.0000 - accuracy: 0.7563 -
precision: 0.7563 - auc: 0.8772 - mae: 0.2435 - mse: 0.1930
loss : 0.674
tp : 540.0
fp : 174.0
tn : 540.0
fn : 174.0
accuracy : 0.756
precision : 0.756
auc : 0.877
mae : 0.244
mse : 0.193
```

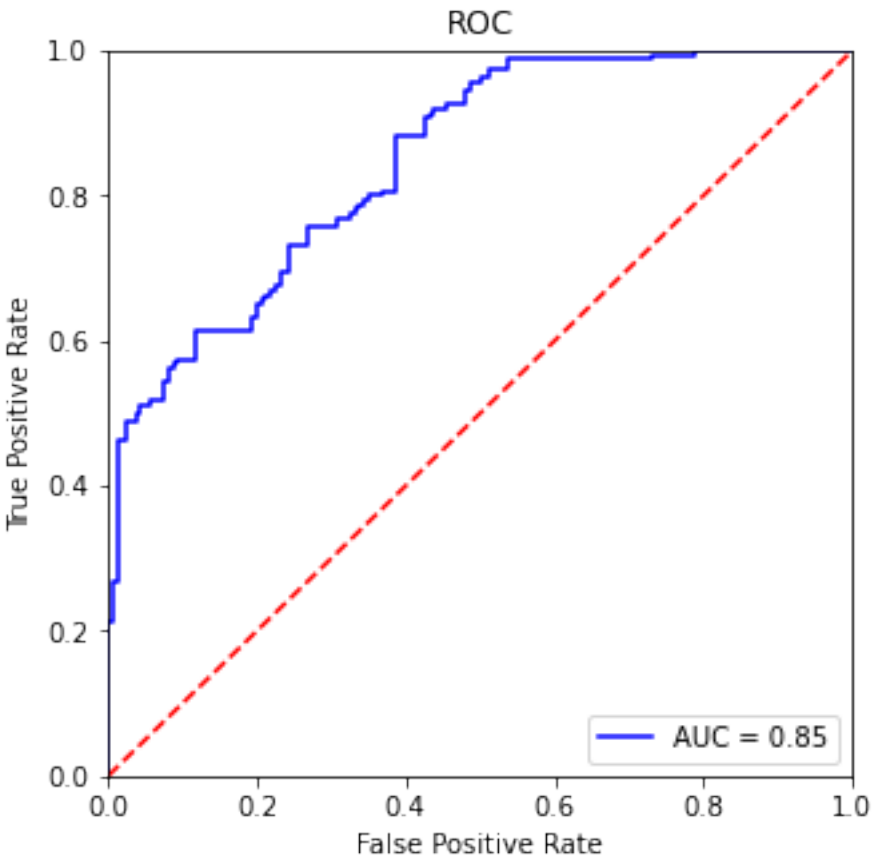
1.1.6 8. Predict with model 1

[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, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0, 1, 1,
0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 0, 0,
1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, 0,
0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1,
0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0]
Real Labels:
 [1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0,
0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 1,
1, 0, 0, 0, 1, 0, 1, 1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 0,
1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 0, 0, 0,
1, 1, 1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1,
1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 0, 1, 0, 0, 0, 1, 0, 1]

Confusion Matrix:
[[80  0]
 [43 37]]

Accuracy: 0.73
```


Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy
Apple__healthy



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.Flatten(),
    tf.keras.layers.BatchNormalization(),
    tf.keras.layers.Dense(8, activation='relu', use_bias=False),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])
```

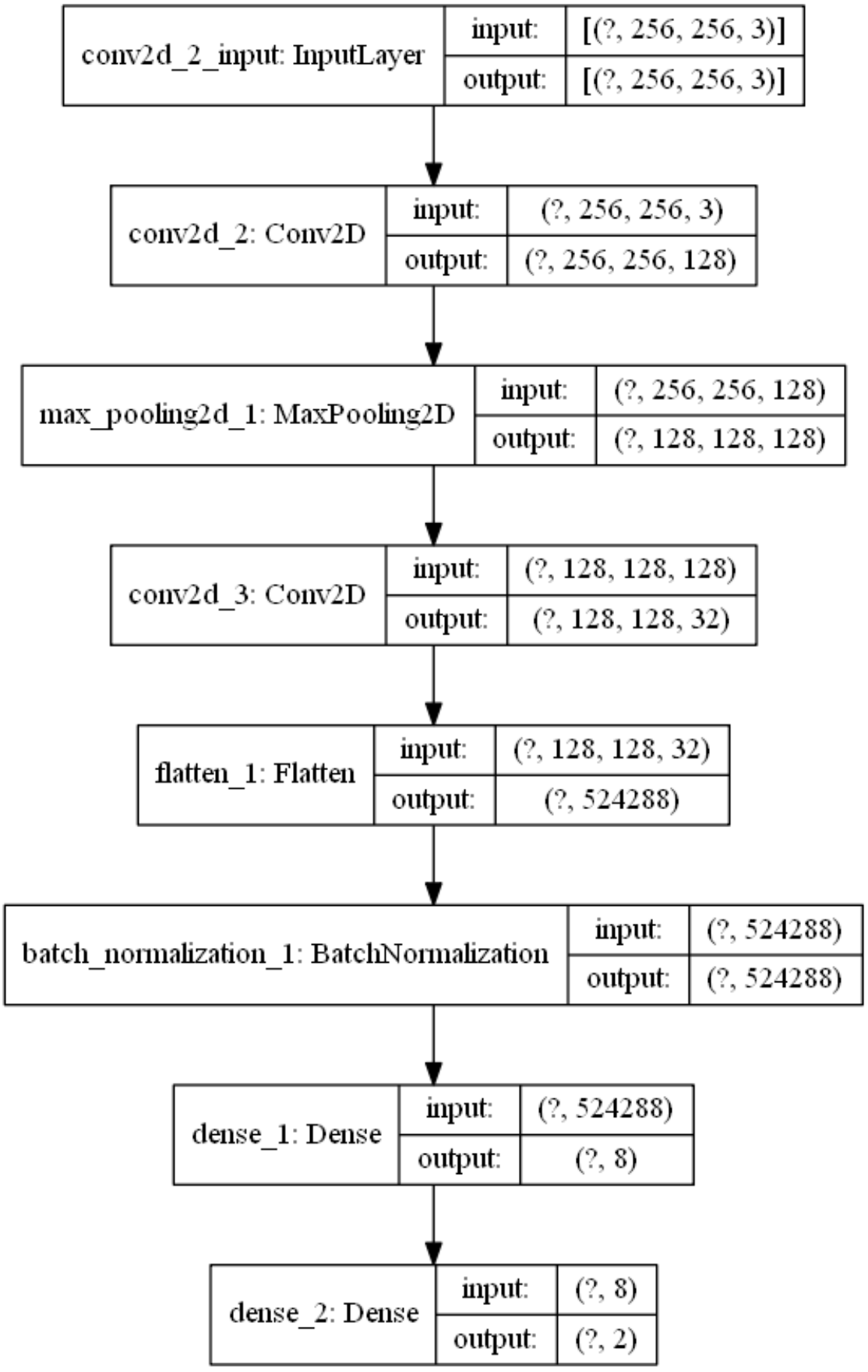
[15]:
```
opt = tf.keras.optimizers.Adam(lr=LEARNING_RATE)
model2.compile(optimizer=opt,
               loss='categorical_crossentropy',
               metrics=METRICS)
```

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_1 (MaxPooling2 (None, 128, 128, 128)     0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 128, 128, 32)      36864
_________________________________________________________________
flatten_1 (Flatten)          (None, 524288)            0
_________________________________________________________________
batch_normalization_1 (Batch (None, 524288)            2097152
_________________________________________________________________
dense_1 (Dense)              (None, 8)                 4194304
_________________________________________________________________
dense_2 (Dense)              (None, 2)                 18
=================================================================
Total params: 6,331,794
Trainable params: 5,283,218
Non-trainable params: 1,048,576
_________________________________________________________________
```

[16]:


conv2d_2_input: InputLayer
input: [(?, 256, 256, 3)]
output: [(?, 256, 256, 3)]
conv2d_2: Conv2D
input: (?, 256, 256, 3)
output: (?, 256, 256, 128)
max_pooling2d_1: MaxPooling2D
input: (?, 256, 256, 128)
output: (?, 128, 128, 128)
conv2d_3: Conv2D
input: (?, 128, 128, 128)
output: (?, 128, 128, 32)
flatten_1: Flatten
input: (?, 128, 128, 32)
output: (?, 524288)
batch_normalization_1: BatchNormalization
input: (?, 524288)
output: (?, 524288)
dense_1: Dense
input: (?, 524288)
output: (?, 8)
dense_2: Dense
input: (?, 8)
output: (?, 2)

1.1.9 5. Training model 2

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

```
Epoch 1/25
46/46 [==============================] - ETA: 0s - loss: 1.5237 - tp: 1601.0000
- fp: 570.0000 - tn: 1602.0000 - fn: 571.0000 - accuracy: 0.7371 - precision:
0.7374 - auc: 0.8231 - mae: 0.2828 - mse: 0.1847
Epoch 00001: val_accuracy improved from -inf to 0.88095, saving model to
./models\Model_2.hdf5
46/46 [==============================] - 16s 356ms/step - loss: 1.5237 - tp:
1601.0000 - fp: 570.0000 - tn: 1602.0000 - fn: 571.0000 - accuracy: 0.7371 -
precision: 0.7374 - auc: 0.8231 - mae: 0.2828 - mse: 0.1847 - val_loss: 0.6423 -
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: 0.7927 - val_mae: 0.4719
- val_mse: 0.2249
Epoch 2/25
46/46 [==============================] - ETA: 0s - loss: 0.3996 - tp: 1203.0000
- fp: 255.0000 - tn: 1203.0000 - fn: 255.0000 - accuracy: 0.8251 - precision:
0.8251 - auc: 0.9098 - mae: 0.2409 - mse: 0.1246
Epoch 00002: val_accuracy did not improve from 0.88095
46/46 [==============================] - 16s 337ms/step - loss: 0.3996 - tp:
1203.0000 - fp: 255.0000 - tn: 1203.0000 - fn: 255.0000 - accuracy: 0.8251 -
precision: 0.8251 - auc: 0.9098 - mae: 0.2409 - mse: 0.1246 - val_loss: 0.6170 -
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: 0.7106 - val_mae: 0.4330
- val_mse: 0.2177
Epoch 3/25
46/46 [==============================] - ETA: 0s - loss: 0.3493 - tp: 1203.0000
- fp: 255.0000 - tn: 1203.0000 - fn: 255.0000 - accuracy: 0.8251 - precision:
0.8251 - auc: 0.9242 - mae: 0.2114 - mse: 0.1108
Epoch 00003: val_accuracy did not improve from 0.88095
46/46 [==============================] - 15s 337ms/step - loss: 0.3493 - tp:
1203.0000 - fp: 255.0000 - tn: 1203.0000 - fn: 255.0000 - accuracy: 0.8251 -
precision: 0.8251 - auc: 0.9242 - mae: 0.2114 - mse: 0.1108 - val_loss: 0.6813 -
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: 0.7126 - val_mae: 0.4370
- val_mse: 0.2519
Epoch 4/25
46/46 [==============================] - ETA: 0s - loss: 0.4091 - tp: 1214.0000
- fp: 244.0000 - tn: 1214.0000 - fn: 244.0000 - accuracy: 0.8326 - precision:
0.8326 - auc: 0.9097 - mae: 0.2365 - mse: 0.1253
Epoch 00004: val_accuracy did not improve from 0.88095
46/46 [==============================] - 16s 339ms/step - loss: 0.4091 - tp:
1214.0000 - fp: 244.0000 - tn: 1214.0000 - fn: 244.0000 - accuracy: 0.8326 -
```

```
precision: 0.8326 - auc: 0.9097 - mae: 0.2365 - mse: 0.1253 - val_loss: 0.5540 -
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: 0.8192 - val_mae: 0.4099
- val_mse: 0.1865
Epoch 5/25
46/46 [==============================] - ETA: 0s - loss: 0.3764 - tp: 1260.0000
- fp: 198.0000 - tn: 1260.0000 - fn: 198.0000 - accuracy: 0.8642 - precision:
0.8642 - auc: 0.9283 - mae: 0.2035 - mse: 0.1081
Epoch 00005: val_accuracy did not improve from 0.88095
46/46 [==============================] - 16s 338ms/step - loss: 0.3764 - tp:
1260.0000 - fp: 198.0000 - tn: 1260.0000 - fn: 198.0000 - accuracy: 0.8642 -
precision: 0.8642 - auc: 0.9283 - mae: 0.2035 - mse: 0.1081 - val_loss: 0.5958 -
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: 0.7104 - val_mae: 0.4102
- val_mse: 0.2120
Epoch 6/25
46/46 [==============================] - ETA: 0s - loss: 0.3550 - tp: 1255.0000
- fp: 203.0000 - tn: 1255.0000 - fn: 203.0000 - accuracy: 0.8608 - precision:
0.8608 - auc: 0.9292 - mae: 0.2149 - mse: 0.1103
Epoch 00006: val_accuracy did not improve from 0.88095
46/46 [==============================] - 15s 337ms/step - loss: 0.3550 - tp:
1255.0000 - fp: 203.0000 - tn: 1255.0000 - fn: 203.0000 - accuracy: 0.8608 -
precision: 0.8608 - auc: 0.9292 - mae: 0.2149 - mse: 0.1103 - val_loss: 0.5137 -
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: 0.8851 - val_mae: 0.3808
- val_mse: 0.1705
Epoch 7/25
46/46 [==============================] - ETA: 0s - loss: 0.3126 - tp: 1262.0000
- fp: 196.0000 - tn: 1262.0000 - fn: 196.0000 - accuracy: 0.8656 - precision:
0.8656 - auc: 0.9432 - mae: 0.1770 - mse: 0.0922
Epoch 00007: val_accuracy did not improve from 0.88095
46/46 [==============================] - 15s 337ms/step - loss: 0.3126 - tp:
1262.0000 - fp: 196.0000 - tn: 1262.0000 - fn: 196.0000 - accuracy: 0.8656 -
precision: 0.8656 - auc: 0.9432 - mae: 0.1770 - mse: 0.0922 - val_loss: 0.5011 -
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: 0.8229 - val_mae: 0.3553
- val_mse: 0.1681
Epoch 8/25
46/46 [==============================] - ETA: 0s - loss: 0.3113 - tp: 1267.0000
- fp: 191.0000 - tn: 1267.0000 - fn: 191.0000 - accuracy: 0.8690 - precision:
0.8690 - auc: 0.9452 - mae: 0.1703 - mse: 0.0906
Epoch 00008: val_accuracy did not improve from 0.88095
46/46 [==============================] - 15s 336ms/step - loss: 0.3113 - tp:
1267.0000 - fp: 191.0000 - tn: 1267.0000 - fn: 191.0000 - accuracy: 0.8690 -
precision: 0.8690 - auc: 0.9452 - mae: 0.1703 - mse: 0.0906 - val_loss: 0.4153 -
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: 0.9164 - val_mae: 0.3073
- val_mse: 0.1294
```

```
Epoch 9/25
46/46 [==============================] - ETA: 0s - loss: 0.3493 - tp: 1233.0000
- fp: 225.0000 - tn: 1233.0000 - fn: 225.0000 - accuracy: 0.8457 - precision:
0.8457 - auc: 0.9292 - mae: 0.2046 - mse: 0.1057
Epoch 00009: val_accuracy did not improve from 0.88095
46/46 [==============================] - 15s 337ms/step - loss: 0.3493 - tp:
1233.0000 - fp: 225.0000 - tn: 1233.0000 - fn: 225.0000 - accuracy: 0.8457 -
precision: 0.8457 - auc: 0.9292 - mae: 0.2046 - mse: 0.1057 - val_loss: 0.4373 -
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: 0.9139 - val_mae: 0.2981
- val_mse: 0.1389
Epoch 10/25
46/46 [==============================] - ETA: 0s - loss: 0.2967 - tp: 1269.0000
- fp: 189.0000 - tn: 1269.0000 - fn: 189.0000 - accuracy: 0.8704 - precision:
0.8704 - auc: 0.9484 - mae: 0.1709 - mse: 0.0893
Epoch 00010: val_accuracy improved from 0.88095 to 0.91270, saving model to
./models\Model_2.hdf5
46/46 [==============================] - 16s 340ms/step - loss: 0.2967 - tp:
1269.0000 - fp: 189.0000 - tn: 1269.0000 - fn: 189.0000 - accuracy: 0.8704 -
precision: 0.8704 - auc: 0.9484 - mae: 0.1709 - mse: 0.0893 - val_loss: 0.3984 -
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: 0.9436 - val_mae: 0.2832
- val_mse: 0.1274
Epoch 11/25
46/46 [==============================] - ETA: 0s - loss: 0.3054 - tp: 1268.0000
- fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 - precision:
0.8697 - auc: 0.9436 - mae: 0.1773 - mse: 0.0926
Epoch 00011: val_accuracy did not improve from 0.91270
46/46 [==============================] - 16s 337ms/step - loss: 0.3054 - tp:
1268.0000 - fp: 190.0000 - tn: 1268.0000 - fn: 190.0000 - accuracy: 0.8697 -
precision: 0.8697 - auc: 0.9436 - mae: 0.1773 - mse: 0.0926 - val_loss: 0.3238 -
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: 0.9498 - val_mae: 0.2324
- val_mse: 0.0968
Epoch 12/25
46/46 [==============================] - ETA: 0s - loss: 0.2572 - tp: 1270.0000
- fp: 188.0000 - tn: 1270.0000 - fn: 188.0000 - accuracy: 0.8711 - precision:
0.8711 - auc: 0.9581 - mae: 0.1660 - mse: 0.0804
Epoch 00012: val_accuracy did not improve from 0.91270
46/46 [==============================] - 16s 337ms/step - loss: 0.2572 - tp:
1270.0000 - fp: 188.0000 - tn: 1270.0000 - fn: 188.0000 - accuracy: 0.8711 -
precision: 0.8711 - auc: 0.9581 - mae: 0.1660 - mse: 0.0804 - val_loss: 0.2632 -
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: 0.9625 - val_mae: 0.1477
- val_mse: 0.0675
Epoch 13/25
46/46 [==============================] - ETA: 0s - loss: 0.2763 - tp: 1272.0000
- fp: 186.0000 - tn: 1272.0000 - fn: 186.0000 - accuracy: 0.8724 - precision:
```

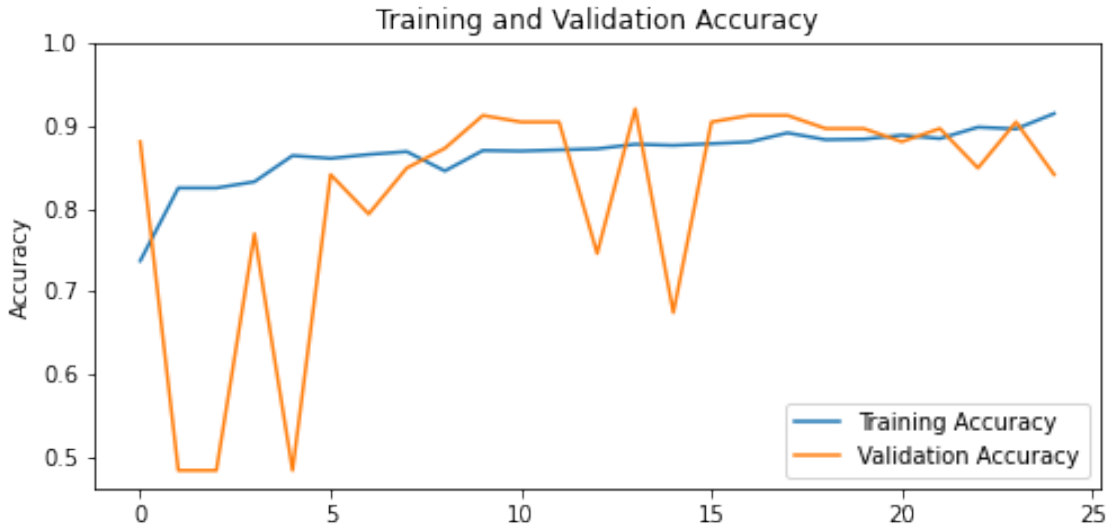
```
0.8724 - auc: 0.9531 - mae: 0.1631 - mse: 0.0839
Epoch 00013: val_accuracy did not improve from 0.91270
46/46 [==============================] - 16s 337ms/step - loss: 0.2763 - tp:
1272.0000 - fp: 186.0000 - tn: 1272.0000 - fn: 186.0000 - accuracy: 0.8724 -
precision: 0.8724 - auc: 0.9531 - mae: 0.1631 - mse: 0.0839 - val_loss: 0.7238 -
val_tp: 94.0000 - val_fp: 32.0000 - val_tn: 94.0000 - val_fn: 32.0000 -
val_accuracy: 0.7460 - val_precision: 0.7460 - val_auc: 0.8046 - val_mae: 0.3092
- val_mse: 0.2111
Epoch 14/25
46/46 [==============================] - ETA: 0s - loss: 0.2703 - tp: 1280.0000
- fp: 178.0000 - tn: 1280.0000 - fn: 178.0000 - accuracy: 0.8779 - precision:
0.8779 - auc: 0.9555 - mae: 0.1658 - mse: 0.0848
Epoch 00014: val_accuracy improved from 0.91270 to 0.92063, saving model to
./models\Model_2.hdf5
46/46 [==============================] - 16s 340ms/step - loss: 0.2703 - tp:
1280.0000 - fp: 178.0000 - tn: 1280.0000 - fn: 178.0000 - accuracy: 0.8779 -
precision: 0.8779 - auc: 0.9555 - mae: 0.1658 - mse: 0.0848 - val_loss: 0.2371 -
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: 0.9664 - val_mae: 0.1388
- val_mse: 0.0661
Epoch 15/25
46/46 [==============================] - ETA: 0s - loss: 0.2711 - tp: 1278.0000
- fp: 180.0000 - tn: 1278.0000 - fn: 180.0000 - accuracy: 0.8765 - precision:
0.8765 - auc: 0.9557 - mae: 0.1580 - mse: 0.0822
Epoch 00015: val_accuracy did not improve from 0.92063
46/46 [==============================] - 15s 337ms/step - loss: 0.2711 - tp:
1278.0000 - fp: 180.0000 - tn: 1278.0000 - fn: 180.0000 - accuracy: 0.8765 -
precision: 0.8765 - auc: 0.9557 - mae: 0.1580 - mse: 0.0822 - val_loss: 1.1575 -
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: 0.7306 - val_mae: 0.3781
- val_mse: 0.2917
Epoch 16/25
46/46 [==============================] - ETA: 0s - loss: 0.3155 - tp: 1281.0000
- fp: 177.0000 - tn: 1281.0000 - fn: 177.0000 - accuracy: 0.8786 - precision:
0.8786 - auc: 0.9481 - mae: 0.1703 - mse: 0.0915
Epoch 00016: val_accuracy did not improve from 0.92063
46/46 [==============================] - 15s 336ms/step - loss: 0.3155 - tp:
1281.0000 - fp: 177.0000 - tn: 1281.0000 - fn: 177.0000 - accuracy: 0.8786 -
precision: 0.8786 - auc: 0.9481 - mae: 0.1703 - mse: 0.0915 - val_loss: 0.3100 -
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: 0.9560 - val_mae: 0.1145
- val_mse: 0.0755
Epoch 17/25
46/46 [==============================] - ETA: 0s - loss: 0.2886 - tp: 1284.0000
- fp: 174.0000 - tn: 1284.0000 - fn: 174.0000 - accuracy: 0.8807 - precision:
0.8807 - auc: 0.9502 - mae: 0.1750 - mse: 0.0891
Epoch 00017: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 337ms/step - loss: 0.2886 - tp:
```

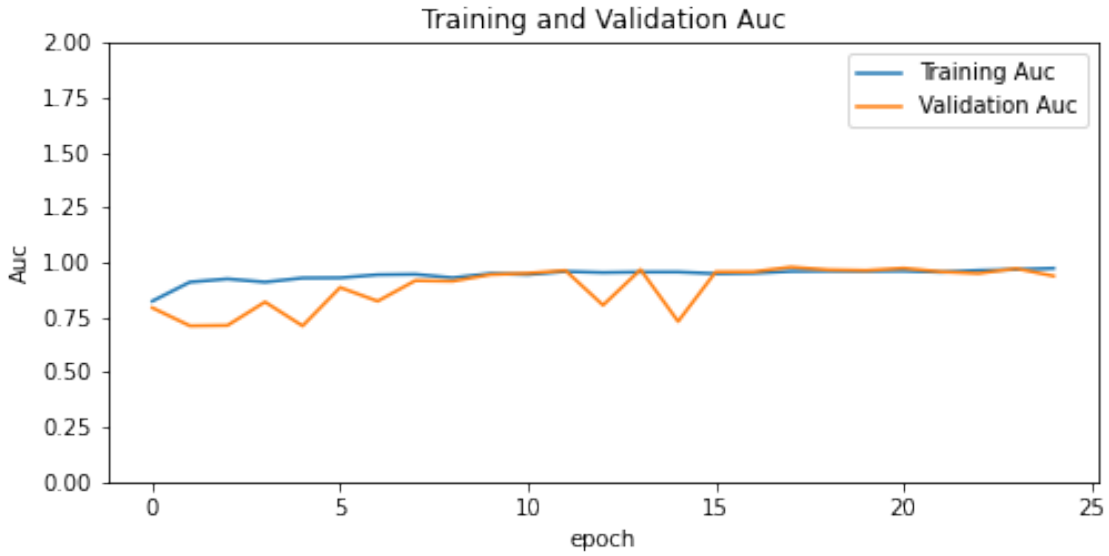
```
1284.0000 - fp: 174.0000 - tn: 1284.0000 - fn: 174.0000 - accuracy: 0.8807 -
precision: 0.8807 - auc: 0.9502 - mae: 0.1750 - mse: 0.0891 - val_loss: 0.3068 -
val_tp: 115.0000 - val_fp: 11.0000 - val_tn: 115.0000 - val_fn: 11.0000 -
val_accuracy: 0.9127 - val_precision: 0.9127 - val_auc: 0.9566 - val_mae: 0.1244
- val_mse: 0.0761
Epoch 18/25
46/46 [==============================] - ETA: 0s - loss: 0.2613 - tp: 1300.0000
- fp: 158.0000 - tn: 1300.0000 - fn: 158.0000 - accuracy: 0.8916 - precision:
0.8916 - auc: 0.9587 - mae: 0.1556 - mse: 0.0792
Epoch 00018: val_accuracy did not improve from 0.92063
46/46 [==============================] - 15s 337ms/step - loss: 0.2613 - tp:
1300.0000 - fp: 158.0000 - tn: 1300.0000 - fn: 158.0000 - accuracy: 0.8916 -
precision: 0.8916 - auc: 0.9587 - mae: 0.1556 - mse: 0.0792 - val_loss: 0.1997 -
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: 0.9780 - val_mae: 0.1086
- val_mse: 0.0627
Epoch 19/25
46/46 [==============================] - ETA: 0s - loss: 0.2557 - tp: 1288.0000
- fp: 170.0000 - tn: 1288.0000 - fn: 170.0000 - accuracy: 0.8834 - precision:
0.8834 - auc: 0.9599 - mae: 0.1571 - mse: 0.0792
Epoch 00019: val_accuracy did not improve from 0.92063
46/46 [==============================] - 15s 336ms/step - loss: 0.2557 - tp:
1288.0000 - fp: 170.0000 - tn: 1288.0000 - fn: 170.0000 - accuracy: 0.8834 -
precision: 0.8834 - auc: 0.9599 - mae: 0.1571 - mse: 0.0792 - val_loss: 0.2441 -
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: 0.9655 - val_mae: 0.1287
- val_mse: 0.0729
Epoch 20/25
46/46 [==============================] - ETA: 0s - loss: 0.2578 - tp: 1289.0000
- fp: 169.0000 - tn: 1289.0000 - fn: 169.0000 - accuracy: 0.8841 - precision:
0.8841 - auc: 0.9593 - mae: 0.1560 - mse: 0.0791
Epoch 00020: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 337ms/step - loss: 0.2578 - tp:
1289.0000 - fp: 169.0000 - tn: 1289.0000 - fn: 169.0000 - accuracy: 0.8841 -
precision: 0.8841 - auc: 0.9593 - mae: 0.1560 - mse: 0.0791 - val_loss: 0.2775 -
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: 0.9625 - val_mae: 0.1463
- val_mse: 0.0716
Epoch 21/25
46/46 [==============================] - ETA: 0s - loss: 0.2556 - tp: 1296.0000
- fp: 162.0000 - tn: 1296.0000 - fn: 162.0000 - accuracy: 0.8889 - precision:
0.8889 - auc: 0.9602 - mae: 0.1470 - mse: 0.0775
Epoch 00021: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 338ms/step - loss: 0.2556 - tp:
1296.0000 - fp: 162.0000 - tn: 1296.0000 - fn: 162.0000 - accuracy: 0.8889 -
precision: 0.8889 - auc: 0.9602 - mae: 0.1470 - mse: 0.0775 - val_loss: 0.2075 -
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: 0.9730 - val_mae: 0.1384
```

```
- val_mse: 0.0602
Epoch 22/25
46/46 [==============================] - ETA: 0s - loss: 0.2728 - tp: 1290.0000
- fp: 168.0000 - tn: 1290.0000 - fn: 168.0000 - accuracy: 0.8848 - precision:
0.8848 - auc: 0.9549 - mae: 0.1708 - mse: 0.0848
Epoch 00022: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 339ms/step - loss: 0.2728 - tp:
1290.0000 - fp: 168.0000 - tn: 1290.0000 - fn: 168.0000 - accuracy: 0.8848 -
precision: 0.8848 - auc: 0.9549 - mae: 0.1708 - mse: 0.0848 - val_loss: 0.2638 -
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: 0.9567 - val_mae: 0.1132
- val_mse: 0.0644
Epoch 23/25
46/46 [==============================] - ETA: 0s - loss: 0.2464 - tp: 1310.0000
- fp: 148.0000 - tn: 1310.0000 - fn: 148.0000 - accuracy: 0.8985 - precision:
0.8985 - auc: 0.9629 - mae: 0.1457 - mse: 0.0745
Epoch 00023: val_accuracy did not improve from 0.92063
46/46 [==============================] - 15s 336ms/step - loss: 0.2464 - tp:
1310.0000 - fp: 148.0000 - tn: 1310.0000 - fn: 148.0000 - accuracy: 0.8985 -
precision: 0.8985 - auc: 0.9629 - mae: 0.1457 - mse: 0.0745 - val_loss: 0.3214 -
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: 0.9493 - val_mae: 0.1553
- val_mse: 0.1005
Epoch 24/25
46/46 [==============================] - ETA: 0s - loss: 0.2337 - tp: 1307.0000
- fp: 151.0000 - tn: 1307.0000 - fn: 151.0000 - accuracy: 0.8964 - precision:
0.8964 - auc: 0.9669 - mae: 0.1397 - mse: 0.0718
Epoch 00024: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 338ms/step - loss: 0.2337 - tp:
1307.0000 - fp: 151.0000 - tn: 1307.0000 - fn: 151.0000 - accuracy: 0.8964 -
precision: 0.8964 - auc: 0.9669 - mae: 0.1397 - mse: 0.0718 - val_loss: 0.2172 -
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: 0.9714 - val_mae: 0.1143
- val_mse: 0.0632
Epoch 25/25
46/46 [==============================] - ETA: 0s - loss: 0.2126 - tp: 1334.0000
- fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 - precision:
0.9150 - auc: 0.9724 - mae: 0.1258 - mse: 0.0643
Epoch 00025: val_accuracy did not improve from 0.92063
46/46 [==============================] - 16s 337ms/step - loss: 0.2126 - tp:
1334.0000 - fp: 124.0000 - tn: 1334.0000 - fn: 124.0000 - accuracy: 0.9150 -
precision: 0.9150 - auc: 0.9724 - mae: 0.1258 - mse: 0.0643 - val_loss: 0.3435 -
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: 0.9373 - val_mae: 0.1670
- val_mse: 0.1010
```

1.1.10 6. Display History 2

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





1.1.11 7. Evaluate the model 2

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

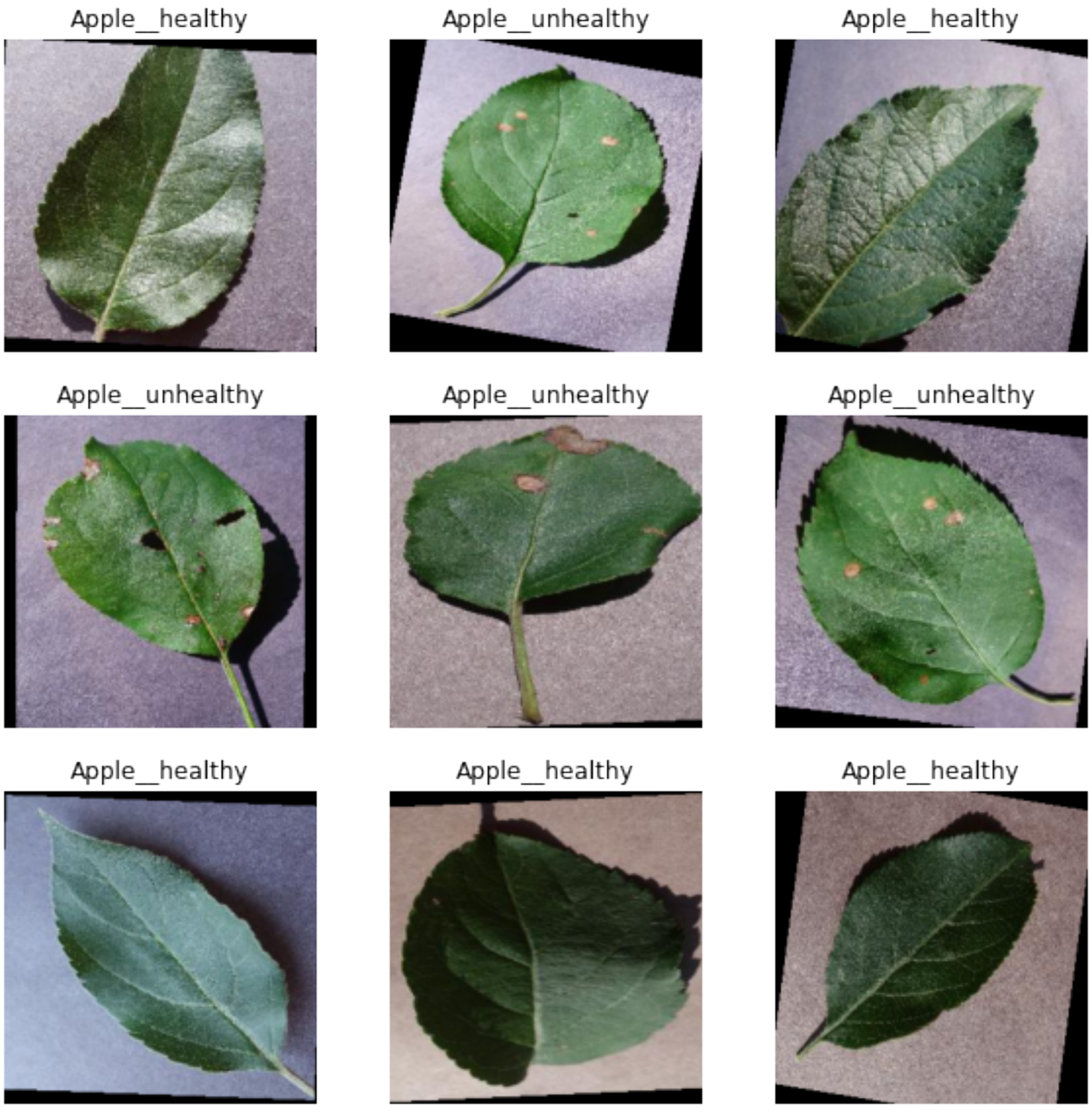
```
714/714 [==============================] - 3s 4ms/step - loss: 0.4902 - tp:
591.0000 - fp: 123.0000 - tn: 591.0000 - fn: 123.0000 - accuracy: 0.8277 -
precision: 0.8277 - auc: 0.9211 - mae: 0.1816 - mse: 0.1376
loss : 0.49
tp : 591.0
fp : 123.0
tn : 591.0
fn : 123.0
accuracy : 0.828
precision : 0.828
auc : 0.921
mae : 0.182
mse : 0.138
```

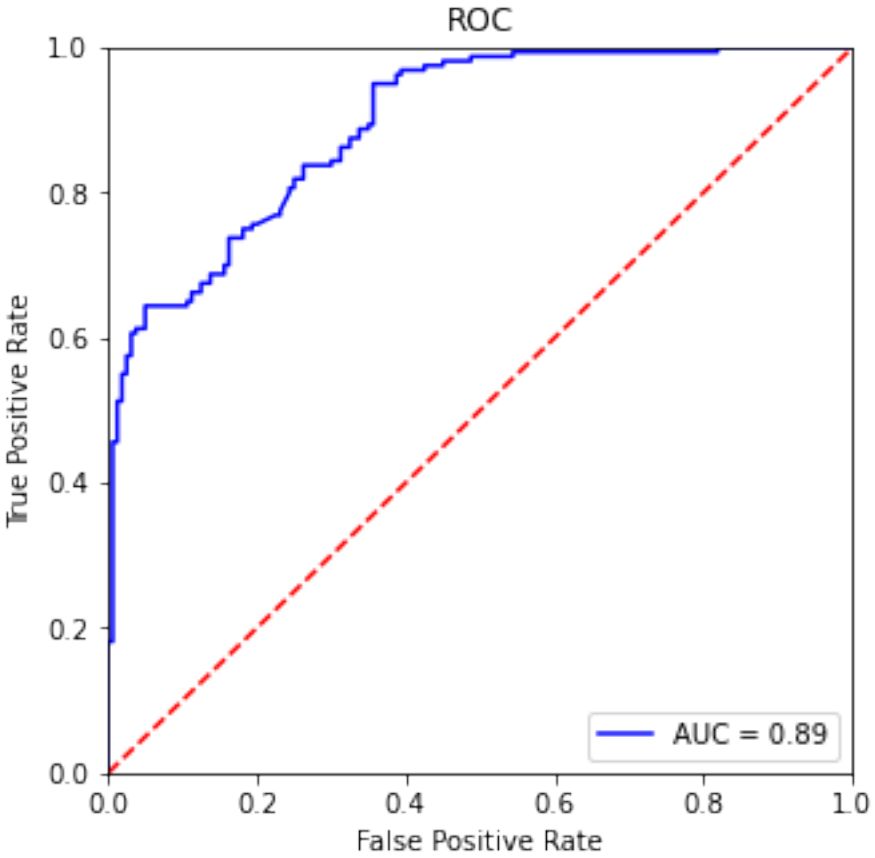
1.1.12 8. Predict with model 2

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

```
Label Predictions:
 [0, 1, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0, 0,
0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1,
0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0,
0, 1, 0, 0, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 1, 0, 0, 0,
0, 0, 0, 0, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0,
0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0]
```

```
Real Labels:
 [0, 1, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0,
0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 0, 0, 1,
0, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 0, 1, 1, 0, 1, 1, 1, 0, 0, 1, 1, 0,
0, 1, 0, 0, 1, 1, 0, 1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0, 1, 1, 0, 1, 1,
1, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 0, 0, 1,
0, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 0, 0, 0, 1, 0, 1, 1, 1, 0, 0, 0, 0, 1, 1]

Confusion Matrix:
[[79  0]
 [37 44]]

Accuracy: 0.77
```





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.Flatten(),
    tf.keras.layers.BatchNormalization(),
    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')
])
```

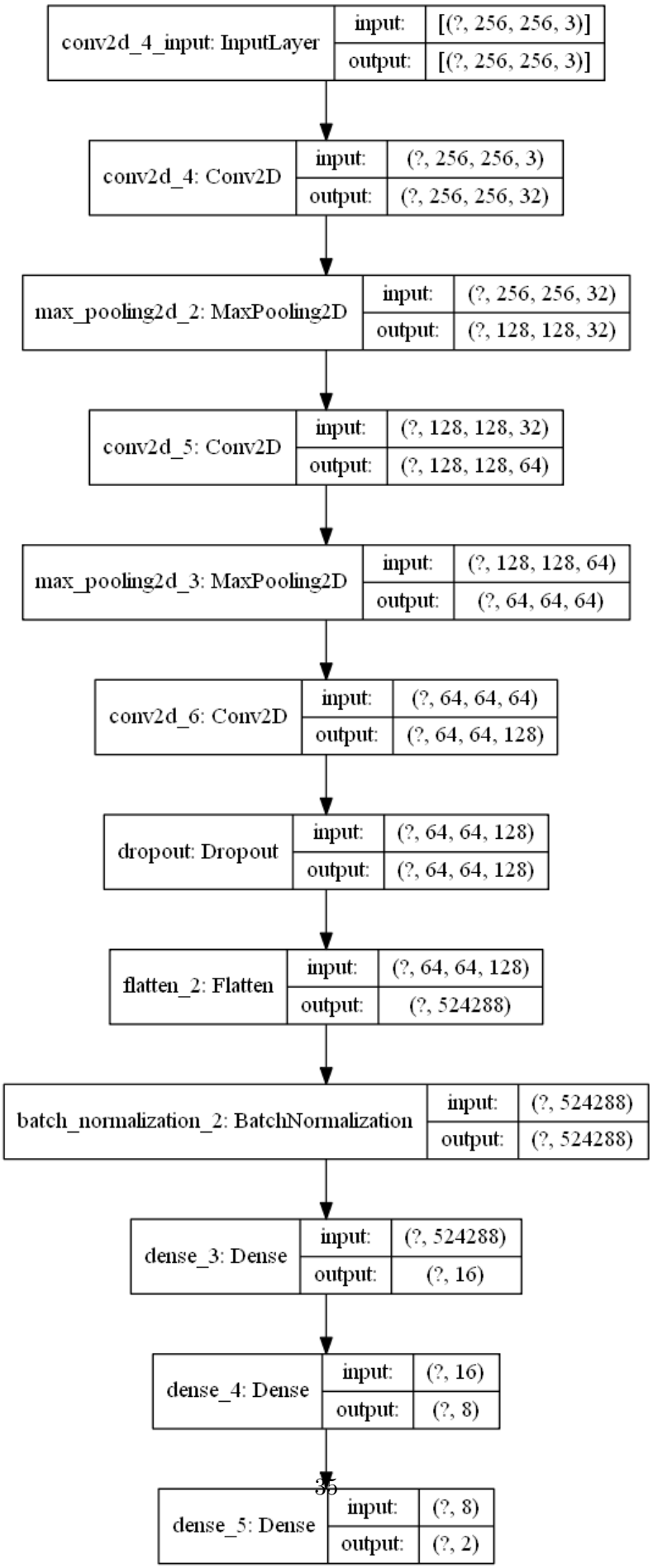
[22]:
```
opt = tf.keras.optimizers.Adam(lr=LEARNING_RATE)
model3.compile(optimizer=opt,
               loss='categorical_crossentropy',
               metrics=METRICS)
```

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_2 (MaxPooling2 (None, 128, 128, 32)      0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 128, 128, 64)      18432
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 64, 64, 64)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 64, 64, 128)       73728
_________________________________________________________________
dropout (Dropout)            (None, 64, 64, 128)       0
_________________________________________________________________
flatten_2 (Flatten)          (None, 524288)            0
_________________________________________________________________
batch_normalization_2 (Batch (None, 524288)            2097152
_________________________________________________________________
dense_3 (Dense)              (None, 16)                8388608
_________________________________________________________________
dense_4 (Dense)              (None, 8)                 128
_________________________________________________________________
dense_5 (Dense)              (None, 2)                 18
=================================================================
Total params: 10,578,930
Trainable params: 9,530,354
Non-trainable params: 1,048,576
```

```
    ------------------------------------------------------------------
[23]:
```


conv2d_4_input: InputLayer
input: [(?, 256, 256, 3)]
output: [(?, 256, 256, 3)]
conv2d_4: Conv2D
input: (?, 256, 256, 3)
output: (?, 256, 256, 32)
max_pooling2d_2: MaxPooling2D
input: (?, 256, 256, 32)
output: (?, 128, 128, 32)
conv2d_5: Conv2D
input: (?, 128, 128, 32)
output: (?, 128, 128, 64)
max_pooling2d_3: MaxPooling2D
input: (?, 128, 128, 64)
output: (?, 64, 64, 64)
conv2d_6: Conv2D
input: (?, 64, 64, 64)
output: (?, 64, 64, 128)
dropout: Dropout
input: (?, 64, 64, 128)
output: (?, 64, 64, 128)
flatten_2: Flatten
input: (?, 64, 64, 128)
output: (?, 524288)
batch_normalization_2: BatchNormalization
input: (?, 524288)
output: (?, 524288)
dense_3: Dense
input: (?, 524288)
output: (?, 16)
dense_4: Dense
input: (?, 16)
output: (?, 8)
dense_5: Dense
input: (?, 8)
output: (?, 2)

1.1.15 5. Training model 3

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

```
Epoch 1/25
46/46 [==============================] - ETA: 0s - loss: 0.6970 - tp: 1698.0000
- fp: 473.0000 - tn: 1699.0000 - fn: 474.0000 - accuracy: 0.7822 - precision:
0.7821 - auc: 0.8745 - mae: 0.2434 - mse: 0.1492
Epoch 00001: val_accuracy improved from -inf to 0.48413, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 17s 363ms/step - loss: 0.6970 - tp:
1698.0000 - fp: 473.0000 - tn: 1699.0000 - fn: 474.0000 - accuracy: 0.7822 -
precision: 0.7821 - auc: 0.8745 - mae: 0.2434 - mse: 0.1492 - val_loss: 1.0023 -
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: 0.4029 - val_mae: 0.5225
- val_mse: 0.3683
Epoch 2/25
46/46 [==============================] - ETA: 0s - loss: 0.3829 - tp: 1211.0000
- fp: 247.0000 - tn: 1211.0000 - fn: 247.0000 - accuracy: 0.8306 - precision:
0.8306 - auc: 0.9195 - mae: 0.2149 - mse: 0.1142
Epoch 00002: val_accuracy improved from 0.48413 to 0.65079, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 16s 341ms/step - loss: 0.3829 - tp:
1211.0000 - fp: 247.0000 - tn: 1211.0000 - fn: 247.0000 - accuracy: 0.8306 -
precision: 0.8306 - auc: 0.9195 - mae: 0.2149 - mse: 0.1142 - val_loss: 0.6082 -
val_tp: 82.0000 - val_fp: 44.0000 - val_tn: 82.0000 - val_fn: 44.0000 -
val_accuracy: 0.6508 - val_precision: 0.6508 - val_auc: 0.7323 - val_mae: 0.4360
- val_mse: 0.2104
Epoch 3/25
46/46 [==============================] - ETA: 0s - loss: 0.2668 - tp: 1307.0000
- fp: 151.0000 - tn: 1307.0000 - fn: 151.0000 - accuracy: 0.8964 - precision:
0.8964 - auc: 0.9598 - mae: 0.1467 - mse: 0.0781
Epoch 00003: val_accuracy improved from 0.65079 to 0.77778, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 16s 341ms/step - loss: 0.2668 - tp:
1307.0000 - fp: 151.0000 - tn: 1307.0000 - fn: 151.0000 - accuracy: 0.8964 -
precision: 0.8964 - auc: 0.9598 - mae: 0.1467 - mse: 0.0781 - val_loss: 0.5386 -
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: 0.8668 - val_mae: 0.4025
- val_mse: 0.1772
Epoch 4/25
46/46 [==============================] - ETA: 0s - loss: 0.2780 - tp: 1287.0000
- fp: 171.0000 - tn: 1287.0000 - fn: 171.0000 - accuracy: 0.8827 - precision:
0.8827 - auc: 0.9553 - mae: 0.1564 - mse: 0.0826
Epoch 00004: val_accuracy improved from 0.77778 to 0.84127, saving model to
```

```
./models\Model_3.hdf5
46/46 [==============================] - 16s 341ms/step - loss: 0.2780 - tp:
1287.0000 - fp: 171.0000 - tn: 1287.0000 - fn: 171.0000 - accuracy: 0.8827 -
precision: 0.8827 - auc: 0.9553 - mae: 0.1564 - mse: 0.0826 - val_loss: 0.4677 -
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: 0.9190 - val_mae: 0.3562
- val_mse: 0.1463
Epoch 5/25
46/46 [==============================] - ETA: 0s - loss: 0.2338 - tp: 1311.0000
- fp: 147.0000 - tn: 1311.0000 - fn: 147.0000 - accuracy: 0.8992 - precision:
0.8992 - auc: 0.9673 - mae: 0.1336 - mse: 0.0707
Epoch 00005: val_accuracy did not improve from 0.84127
46/46 [==============================] - 16s 338ms/step - loss: 0.2338 - tp:
1311.0000 - fp: 147.0000 - tn: 1311.0000 - fn: 147.0000 - accuracy: 0.8992 -
precision: 0.8992 - auc: 0.9673 - mae: 0.1336 - mse: 0.0707 - val_loss: 0.6285 -
val_tp: 76.0000 - val_fp: 50.0000 - val_tn: 76.0000 - val_fn: 50.0000 -
val_accuracy: 0.6032 - val_precision: 0.6032 - val_auc: 0.7448 - val_mae: 0.3724
- val_mse: 0.2257
Epoch 6/25
46/46 [==============================] - ETA: 0s - loss: 0.1944 - tp: 1351.0000
- fp: 107.0000 - tn: 1351.0000 - fn: 107.0000 - accuracy: 0.9266 - precision:
0.9266 - auc: 0.9764 - mae: 0.1096 - mse: 0.0564
Epoch 00006: val_accuracy improved from 0.84127 to 0.86508, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 16s 343ms/step - loss: 0.1944 - tp:
1351.0000 - fp: 107.0000 - tn: 1351.0000 - fn: 107.0000 - accuracy: 0.9266 -
precision: 0.9266 - auc: 0.9764 - mae: 0.1096 - mse: 0.0564 - val_loss: 0.3294 -
val_tp: 109.0000 - val_fp: 17.0000 - val_tn: 109.0000 - val_fn: 17.0000 -
val_accuracy: 0.8651 - val_precision: 0.8651 - val_auc: 0.9376 - val_mae: 0.2196
- val_mse: 0.0992
Epoch 7/25
46/46 [==============================] - ETA: 0s - loss: 0.1899 - tp: 1341.0000
- fp: 117.0000 - tn: 1341.0000 - fn: 117.0000 - accuracy: 0.9198 - precision:
0.9198 - auc: 0.9783 - mae: 0.1086 - mse: 0.0573
Epoch 00007: val_accuracy did not improve from 0.86508
46/46 [==============================] - 15s 336ms/step - loss: 0.1899 - tp:
1341.0000 - fp: 117.0000 - tn: 1341.0000 - fn: 117.0000 - accuracy: 0.9198 -
precision: 0.9198 - auc: 0.9783 - mae: 0.1086 - mse: 0.0573 - val_loss: 0.3818 -
val_tp: 103.0000 - val_fp: 23.0000 - val_tn: 103.0000 - val_fn: 23.0000 -
val_accuracy: 0.8175 - val_precision: 0.8175 - val_auc: 0.9089 - val_mae: 0.2467
- val_mse: 0.1223
Epoch 8/25
46/46 [==============================] - ETA: 0s - loss: 0.1586 - tp: 1369.0000
- fp: 89.0000 - tn: 1369.0000 - fn: 89.0000 - accuracy: 0.9390 - precision:
0.9390 - auc: 0.9850 - mae: 0.0868 - mse: 0.0462
Epoch 00008: val_accuracy improved from 0.86508 to 0.94444, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 16s 342ms/step - loss: 0.1586 - tp:
```

```
1369.0000 - fp: 89.0000 - tn: 1369.0000 - fn: 89.0000 - accuracy: 0.9390 -
precision: 0.9390 - auc: 0.9850 - mae: 0.0868 - mse: 0.0462 - val_loss: 0.1428 -
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: 0.9940 - val_mae: 0.1146
- val_mse: 0.0342
Epoch 9/25
46/46 [==============================] - ETA: 0s - loss: 0.1900 - tp: 1343.0000
- fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 - precision:
0.9211 - auc: 0.9787 - mae: 0.1023 - mse: 0.0576
Epoch 00009: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 339ms/step - loss: 0.1900 - tp:
1343.0000 - fp: 115.0000 - tn: 1343.0000 - fn: 115.0000 - accuracy: 0.9211 -
precision: 0.9211 - auc: 0.9787 - mae: 0.1023 - mse: 0.0576 - val_loss: 0.2806 -
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: 0.9519 - val_mae: 0.1747
- val_mse: 0.0858
Epoch 10/25
46/46 [==============================] - ETA: 0s - loss: 0.1810 - tp: 1362.0000
- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision:
0.9342 - auc: 0.9802 - mae: 0.0948 - mse: 0.0524
Epoch 00010: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 339ms/step - loss: 0.1810 - tp:
1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 -
precision: 0.9342 - auc: 0.9802 - mae: 0.0948 - mse: 0.0524 - val_loss: 0.2342 -
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: 0.9671 - val_mae: 0.1268
- val_mse: 0.0688
Epoch 11/25
46/46 [==============================] - ETA: 0s - loss: 0.1450 - tp: 1376.0000
- fp: 82.0000 - tn: 1376.0000 - fn: 82.0000 - accuracy: 0.9438 - precision:
0.9438 - auc: 0.9872 - mae: 0.0851 - mse: 0.0427
Epoch 00011: val_accuracy did not improve from 0.94444
46/46 [==============================] - 15s 337ms/step - loss: 0.1450 - tp:
1376.0000 - fp: 82.0000 - tn: 1376.0000 - fn: 82.0000 - accuracy: 0.9438 -
precision: 0.9438 - auc: 0.9872 - mae: 0.0851 - mse: 0.0427 - val_loss: 0.4589 -
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: 0.8862 - val_mae: 0.2523
- val_mse: 0.1571
Epoch 12/25
46/46 [==============================] - ETA: 0s - loss: 0.1727 - tp: 1362.0000
- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision:
0.9342 - auc: 0.9825 - mae: 0.0907 - mse: 0.0491
Epoch 00012: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 337ms/step - loss: 0.1727 - tp:
1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 -
precision: 0.9342 - auc: 0.9825 - mae: 0.0907 - mse: 0.0491 - val_loss: 0.7893 -
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: 0.9302 - val_mae: 0.1678
```

```
- val_mse: 0.1347
Epoch 13/25
46/46 [==============================] - ETA: 0s - loss: 0.1874 - tp: 1346.0000
- fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 - precision:
0.9232 - auc: 0.9789 - mae: 0.1050 - mse: 0.0565
Epoch 00013: val_accuracy did not improve from 0.94444
46/46 [==============================] - 15s 336ms/step - loss: 0.1874 - tp:
1346.0000 - fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 -
precision: 0.9232 - auc: 0.9789 - mae: 0.1050 - mse: 0.0565 - val_loss: 0.2475 -
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: 0.9661 - val_mae: 0.1241
- val_mse: 0.0747
Epoch 14/25
46/46 [==============================] - ETA: 0s - loss: 0.2294 - tp: 1338.0000
- fp: 120.0000 - tn: 1338.0000 - fn: 120.0000 - accuracy: 0.9177 - precision:
0.9177 - auc: 0.9737 - mae: 0.1045 - mse: 0.0591
Epoch 00014: val_accuracy did not improve from 0.94444
46/46 [==============================] - 15s 337ms/step - loss: 0.2294 - tp:
1338.0000 - fp: 120.0000 - tn: 1338.0000 - fn: 120.0000 - accuracy: 0.9177 -
precision: 0.9177 - auc: 0.9737 - mae: 0.1045 - mse: 0.0591 - val_loss: 3.1974 -
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: 0.8052 - val_mae: 0.2332
- val_mse: 0.2057
Epoch 15/25
46/46 [==============================] - ETA: 0s - loss: 0.4062 - tp: 1273.0000
- fp: 185.0000 - tn: 1273.0000 - fn: 185.0000 - accuracy: 0.8731 - precision:
0.8731 - auc: 0.9368 - mae: 0.1704 - mse: 0.0972
Epoch 00015: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 338ms/step - loss: 0.4062 - tp:
1273.0000 - fp: 185.0000 - tn: 1273.0000 - fn: 185.0000 - accuracy: 0.8731 -
precision: 0.8731 - auc: 0.9368 - mae: 0.1704 - mse: 0.0972 - val_loss: 3.5240 -
val_tp: 74.0000 - val_fp: 52.0000 - val_tn: 74.0000 - val_fn: 52.0000 -
val_accuracy: 0.5873 - val_precision: 0.5873 - val_auc: 0.6316 - val_mae: 0.3969
- val_mse: 0.3806
Epoch 16/25
46/46 [==============================] - ETA: 0s - loss: 0.3335 - tp: 1261.0000
- fp: 197.0000 - tn: 1261.0000 - fn: 197.0000 - accuracy: 0.8649 - precision:
0.8649 - auc: 0.9453 - mae: 0.1719 - mse: 0.0928
Epoch 00016: val_accuracy did not improve from 0.94444
46/46 [==============================] - 15s 336ms/step - loss: 0.3335 - tp:
1261.0000 - fp: 197.0000 - tn: 1261.0000 - fn: 197.0000 - accuracy: 0.8649 -
precision: 0.8649 - auc: 0.9453 - mae: 0.1719 - mse: 0.0928 - val_loss: 0.7702 -
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: 0.8209 - val_mae: 0.3237
- val_mse: 0.1806
Epoch 17/25
46/46 [==============================] - ETA: 0s - loss: 0.2509 - tp: 1336.0000
- fp: 122.0000 - tn: 1336.0000 - fn: 122.0000 - accuracy: 0.9163 - precision:
```

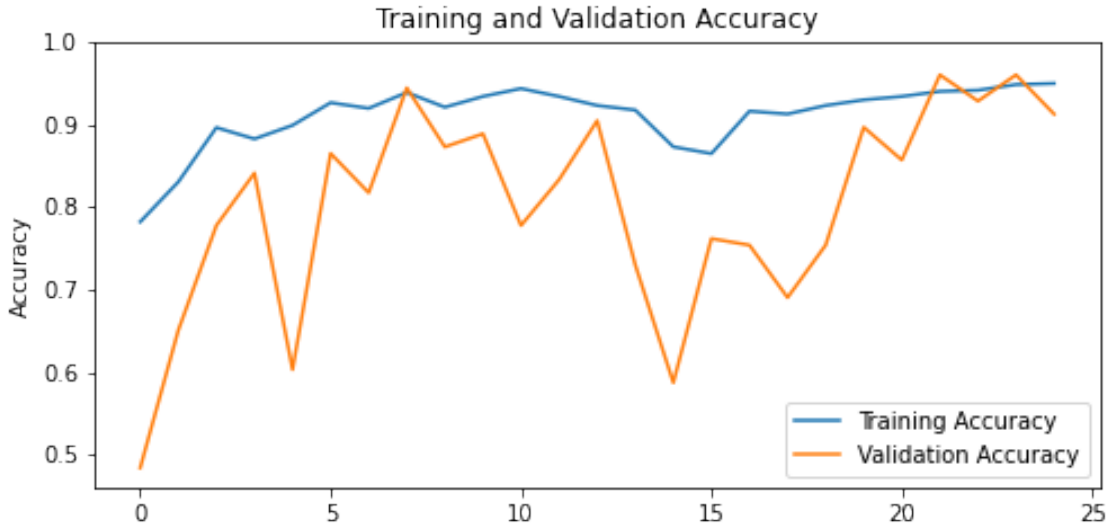
```
0.9163 - auc: 0.9675 - mae: 0.1187 - mse: 0.0657
Epoch 00017: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 340ms/step - loss: 0.2509 - tp:
1336.0000 - fp: 122.0000 - tn: 1336.0000 - fn: 122.0000 - accuracy: 0.9163 -
precision: 0.9163 - auc: 0.9675 - mae: 0.1187 - mse: 0.0657 - val_loss: 6.0998 -
val_tp: 95.0000 - val_fp: 31.0000 - val_tn: 95.0000 - val_fn: 31.0000 -
val_accuracy: 0.7540 - val_precision: 0.7540 - val_auc: 0.7640 - val_mae: 0.2522
- val_mse: 0.2398
Epoch 18/25
46/46 [==============================] - ETA: 0s - loss: 0.2675 - tp: 1331.0000
- fp: 127.0000 - tn: 1331.0000 - fn: 127.0000 - accuracy: 0.9129 - precision:
0.9129 - auc: 0.9726 - mae: 0.1161 - mse: 0.0627
Epoch 00018: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 342ms/step - loss: 0.2675 - tp:
1331.0000 - fp: 127.0000 - tn: 1331.0000 - fn: 127.0000 - accuracy: 0.9129 -
precision: 0.9129 - auc: 0.9726 - mae: 0.1161 - mse: 0.0627 - val_loss: 4.9136 -
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: 0.7388 - val_mae: 0.3282
- val_mse: 0.2721
Epoch 19/25
46/46 [==============================] - ETA: 0s - loss: 0.1886 - tp: 1346.0000
- fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 - precision:
0.9232 - auc: 0.9780 - mae: 0.1111 - mse: 0.0566
Epoch 00019: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 337ms/step - loss: 0.1886 - tp:
1346.0000 - fp: 112.0000 - tn: 1346.0000 - fn: 112.0000 - accuracy: 0.9232 -
precision: 0.9232 - auc: 0.9780 - mae: 0.1111 - mse: 0.0566 - val_loss: 2.4488 -
val_tp: 95.0000 - val_fp: 31.0000 - val_tn: 95.0000 - val_fn: 31.0000 -
val_accuracy: 0.7540 - val_precision: 0.7540 - val_auc: 0.8317 - val_mae: 0.2479
- val_mse: 0.2021
Epoch 20/25
46/46 [==============================] - ETA: 0s - loss: 0.1908 - tp: 1356.0000
- fp: 102.0000 - tn: 1356.0000 - fn: 102.0000 - accuracy: 0.9300 - precision:
0.9300 - auc: 0.9807 - mae: 0.0965 - mse: 0.0524
Epoch 00020: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 340ms/step - loss: 0.1908 - tp:
1356.0000 - fp: 102.0000 - tn: 1356.0000 - fn: 102.0000 - accuracy: 0.9300 -
precision: 0.9300 - auc: 0.9807 - mae: 0.0965 - mse: 0.0524 - val_loss: 0.2139 -
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: 0.9712 - val_mae: 0.1072
- val_mse: 0.0610
Epoch 21/25
46/46 [==============================] - ETA: 0s - loss: 0.1761 - tp: 1362.0000
- fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 - precision:
0.9342 - auc: 0.9818 - mae: 0.0907 - mse: 0.0479
Epoch 00021: val_accuracy did not improve from 0.94444
46/46 [==============================] - 16s 339ms/step - loss: 0.1761 - tp:
1362.0000 - fp: 96.0000 - tn: 1362.0000 - fn: 96.0000 - accuracy: 0.9342 -
```

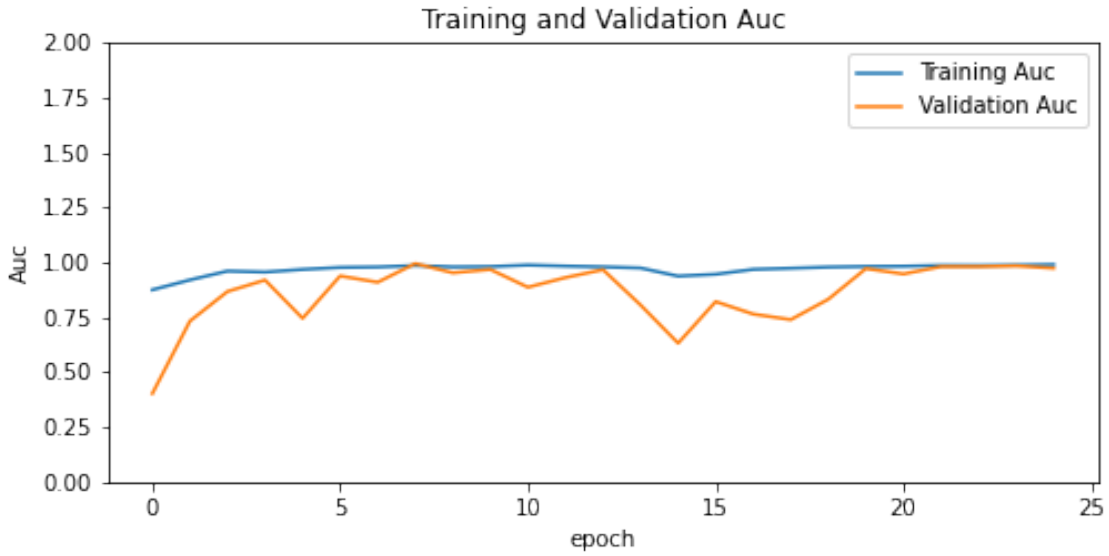
```
precision: 0.9342 - auc: 0.9818 - mae: 0.0907 - mse: 0.0479 - val_loss: 0.3991 -
val_tp: 108.0000 - val_fp: 18.0000 - val_tn: 108.0000 - val_fn: 18.0000 -
val_accuracy: 0.8571 - val_precision: 0.8571 - val_auc: 0.9467 - val_mae: 0.1449
- val_mse: 0.1120
Epoch 22/25
46/46 [==============================] - ETA: 0s - loss: 0.1557 - tp: 1371.0000
- fp: 87.0000 - tn: 1371.0000 - fn: 87.0000 - accuracy: 0.9403 - precision:
0.9403 - auc: 0.9855 - mae: 0.0850 - mse: 0.0457
Epoch 00022: val_accuracy improved from 0.94444 to 0.96032, saving model to
./models\Model_3.hdf5
46/46 [==============================] - 16s 345ms/step - loss: 0.1557 - tp:
1371.0000 - fp: 87.0000 - tn: 1371.0000 - fn: 87.0000 - accuracy: 0.9403 -
precision: 0.9403 - auc: 0.9855 - mae: 0.0850 - mse: 0.0457 - val_loss: 0.1881 -
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: 0.9799 - val_mae: 0.0697
- val_mse: 0.0360
Epoch 23/25
46/46 [==============================] - ETA: 0s - loss: 0.1534 - tp: 1373.0000
- fp: 85.0000 - tn: 1373.0000 - fn: 85.0000 - accuracy: 0.9417 - precision:
0.9417 - auc: 0.9851 - mae: 0.0890 - mse: 0.0442
Epoch 00023: val_accuracy did not improve from 0.96032
46/46 [==============================] - 16s 340ms/step - loss: 0.1534 - tp:
1373.0000 - fp: 85.0000 - tn: 1373.0000 - fn: 85.0000 - accuracy: 0.9417 -
precision: 0.9417 - auc: 0.9851 - mae: 0.0890 - mse: 0.0442 - val_loss: 0.1960 -
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: 0.9801 - val_mae: 0.0826
- val_mse: 0.0550
Epoch 24/25
46/46 [==============================] - ETA: 0s - loss: 0.1472 - tp: 1383.0000
- fp: 75.0000 - tn: 1383.0000 - fn: 75.0000 - accuracy: 0.9486 - precision:
0.9486 - auc: 0.9865 - mae: 0.0802 - mse: 0.0430
Epoch 00024: val_accuracy did not improve from 0.96032
46/46 [==============================] - 16s 339ms/step - loss: 0.1472 - tp:
1383.0000 - fp: 75.0000 - tn: 1383.0000 - fn: 75.0000 - accuracy: 0.9486 -
precision: 0.9486 - auc: 0.9865 - mae: 0.0802 - mse: 0.0430 - val_loss: 0.2260 -
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: 0.9836 - val_mae: 0.0630
- val_mse: 0.0378
Epoch 25/25
46/46 [==============================] - ETA: 0s - loss: 0.1331 - tp: 1385.0000
- fp: 73.0000 - tn: 1385.0000 - fn: 73.0000 - accuracy: 0.9499 - precision:
0.9499 - auc: 0.9893 - mae: 0.0766 - mse: 0.0393
Epoch 00025: val_accuracy did not improve from 0.96032
46/46 [==============================] - 16s 337ms/step - loss: 0.1331 - tp:
1385.0000 - fp: 73.0000 - tn: 1385.0000 - fn: 73.0000 - accuracy: 0.9499 -
precision: 0.9499 - auc: 0.9893 - mae: 0.0766 - mse: 0.0393 - val_loss: 0.2558 -
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: 0.9729 - val_mae: 0.0954
```

- val_mse: 0.0657

1.1.16 6. Display History 3

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





1.1.17 7. Evaluate the model 3

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

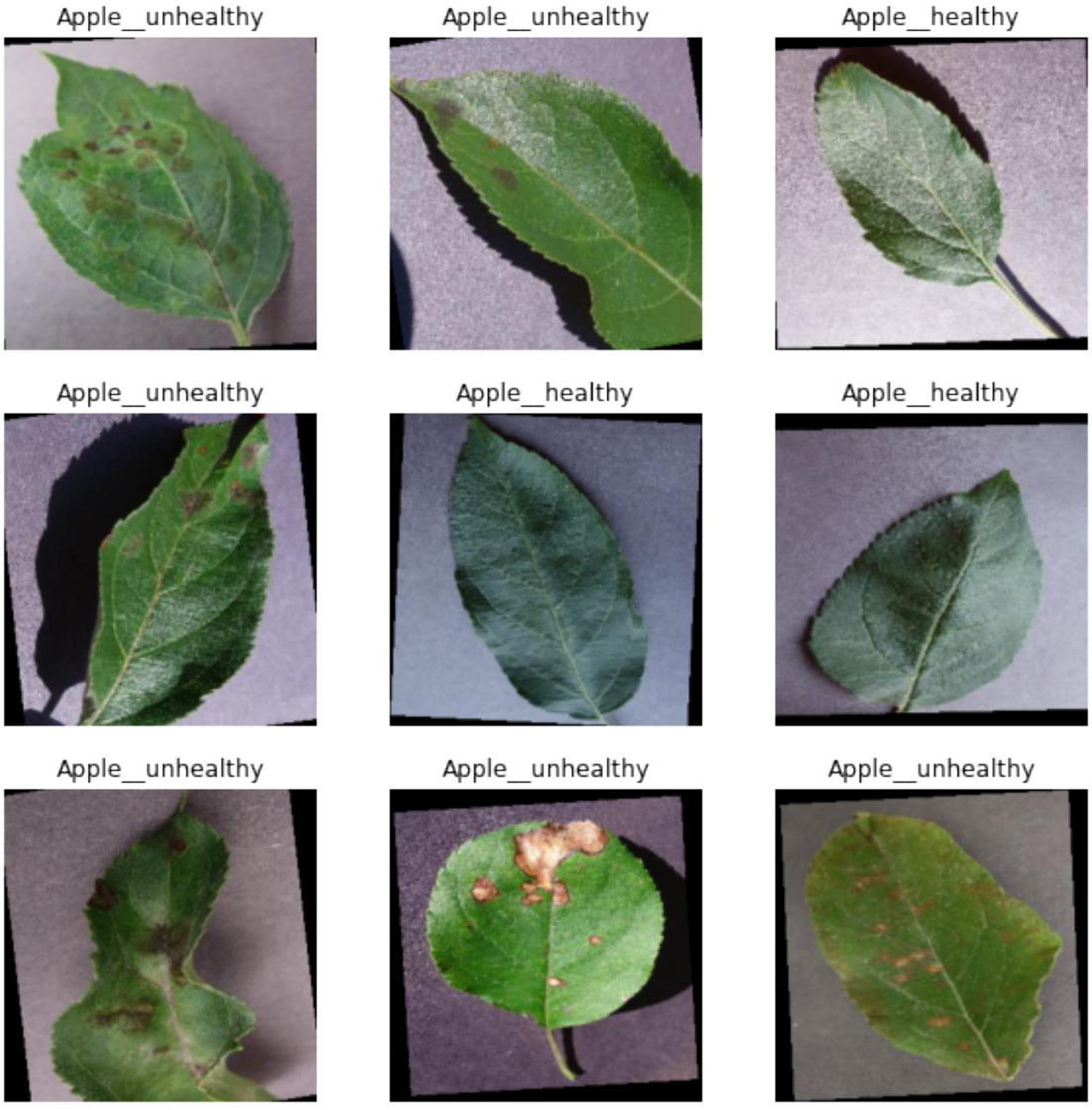
```
714/714 [==============================] - 3s 5ms/step - loss: 0.3559 - tp:
652.0000 - fp: 62.0000 - tn: 652.0000 - fn: 62.0000 - accuracy: 0.9132 -
precision: 0.9132 - auc: 0.9652 - mae: 0.0998 - mse: 0.0655
loss : 0.356
tp : 652.0
fp : 62.0
tn : 652.0
fn : 62.0
accuracy : 0.913
precision : 0.913
auc : 0.965
mae : 0.1
mse : 0.066
```

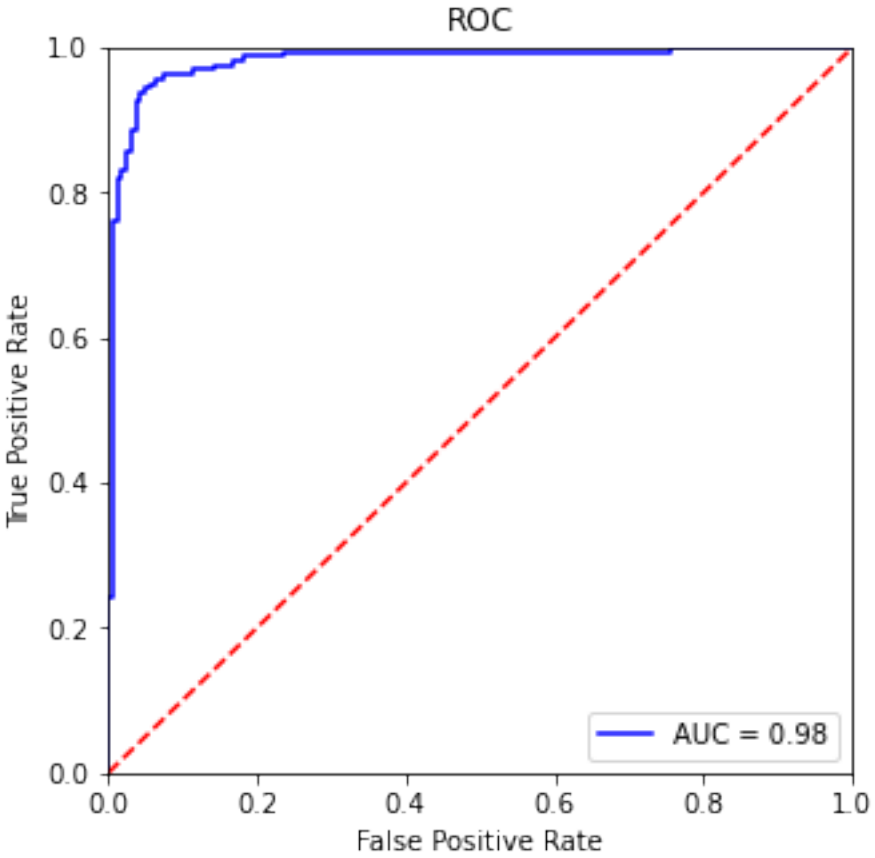
1.1.18 8. Predict with model 3

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

```
Label Predictions:
 [1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1,
1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1,
1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 0, 1, 0,
0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 0,
0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 1, 0, 1,
0, 1, 1, 1, 1, 0, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 1, 1, 0]
```

```
Real Labels:
 [1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 1, 0, 1, 1,
1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 1,
1, 1, 0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0,
0, 1, 1, 0, 0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 1,
0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 1, 0, 1, 0, 1,
0, 1, 1, 1, 1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 1, 0]

Confusion Matrix:
[[75  4]
 [ 5 76]]

Accuracy: 0.94
```





1.1.19 9. Save test model

[28]:
```
model3.save(MODEL_NAME)
```

1.1.20 10. Load test model

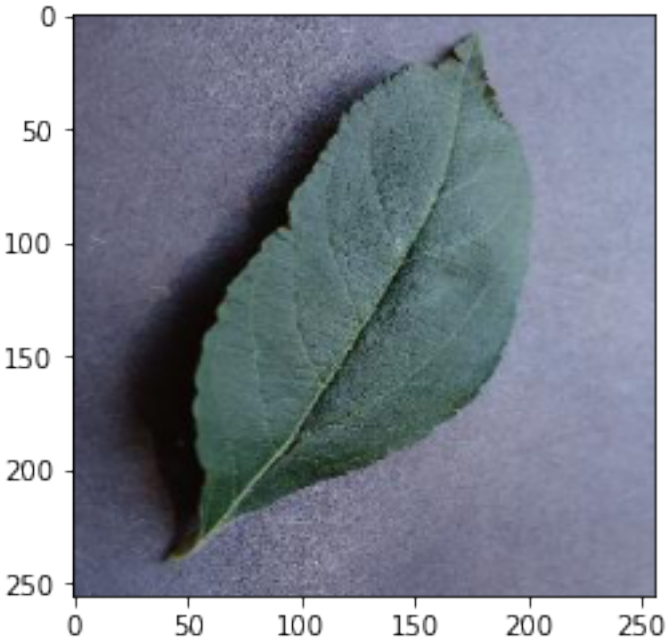
[29]:
```
loaded_model = tf.keras.models.load_model(MODEL_NAME)
```

1.1.21 11. Test loaded model on image:

[30]:
```
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)
```

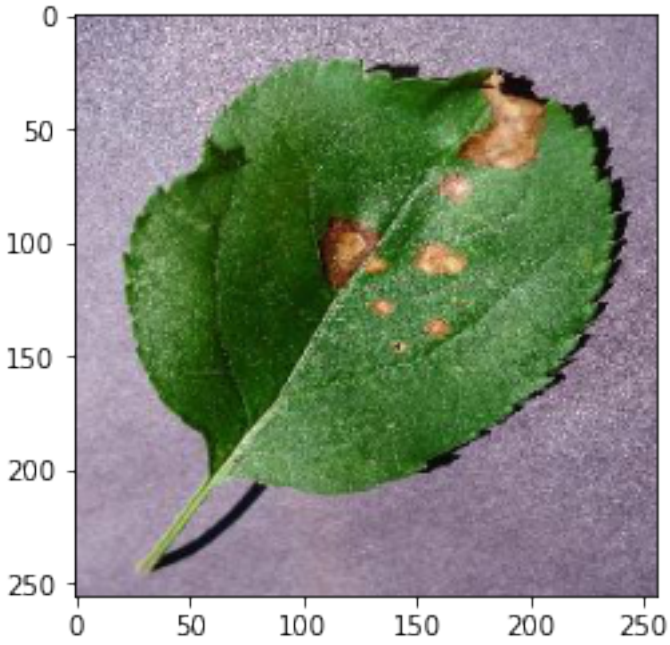
```
print('Expected result: [1, 0] \n')
print('Result: ', predictions, '\n')
```

```
Expected result: [1, 0]

Result:  [[1. 0.]]
```



[31]:
```
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 much better results (could achieve 95% accuracy), which however were quite unstable (accuracy sometimes was 50%). Changing the batch normalization processing after the flattening increased the amount of parameters for the model to learn. Through this better results were achieved with more layers.
- The batch size of 32 worked the best when trying these models.
- Adding a small dropout also had a positive effect.
- Models with more than three convolution layers did not improve the models at all and were therefore not added to the final tests.

1.2.1 Model 1:

This is a very simple model that worked very well. Showing that a small amount of layers can already create a 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 not much better than model 1, which uses a lot fewer layers. This model did not increase the parameters to learn,

compared to model 1. The chosen direction to decrease the neurons gradually seems to not be a good choice.

1.2.3 Model 3:

This model seems to perform the best, based on the false positive and false negative validation. Decreasing the size of the image, then increasing the neurons and leaving the amount of layers around 2-3 seemed to have the best effect.

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.

[ ]:

[ ]: