Classify_imgs

October 8, 2020

[1]:

```
from tensorflow import keras
from imutils import paths
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import SGD
import numpy as np
from tensorflow.keras.layers import Dense, GlobalAveragePooling2D
from tensorflow.keras.applications.densenet import DenseNet121
from tensorflow.keras.models import Model
```

[2]:

```
width, height = 128, 128
```

[3]:

```
Densebase = DenseNet121(include_top=False, input_shape=(
    width, height, 3), weights='imagenet', classes=2)

x = Densebase.output
x = GlobalAveragePooling2D()(x)
x = Dense(1024, activation='relu')(x)
predictions = Dense(2, activation='sigmoid')(x)
model = Model(inputs=Densebase.input,
              outputs=predictions)

model.summary()
```

```
_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block4_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block4_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block4_1_relu (Activation (None, 4, 4, 128)    0
conv5_block4_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block4_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block4_1_relu[0][0]
--------------------------------------------------------------------------------
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```

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conv5_block4_concat (Concatenat (None, 4, 4, 640)    0
conv5_block3_concat[0][0]
conv5_block4_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_0_bn (BatchNormali (None, 4, 4, 640)    2560
conv5_block4_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_0_relu (Activation (None, 4, 4, 640)    0
conv5_block5_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_1_conv (Conv2D)    (None, 4, 4, 128)    81920
conv5_block5_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block5_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_1_relu (Activation (None, 4, 4, 128)    0
conv5_block5_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block5_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block5_concat (Concatenat (None, 4, 4, 672)    0
conv5_block4_concat[0][0]
conv5_block5_2_conv[0][0]
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------------------
conv5_block6_0_bn (BatchNormali (None, 4, 4, 672)    2688
conv5_block5_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block6_0_relu (Activation (None, 4, 4, 672)    0
conv5_block6_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block6_1_conv (Conv2D)    (None, 4, 4, 128)    86016
conv5_block6_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block6_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block6_1_conv[0][0]
```

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------------------
conv5_block6_1_relu (Activation (None, 4, 4, 128)    0
conv5_block6_1_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block6_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block6_1_relu[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block6_concat (Concatenat (None, 4, 4, 704)    0
conv5_block5_concat[0][0]
conv5_block6_2_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_0_bn (BatchNormali (None, 4, 4, 704)    2816
conv5_block6_concat[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_0_relu (Activation (None, 4, 4, 704)    0
conv5_block7_0_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_1_conv (Conv2D)    (None, 4, 4, 128)    90112
conv5_block7_0_relu[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block7_1_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_1_relu (Activation (None, 4, 4, 128)    0
conv5_block7_1_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block7_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block7_1_relu[0][0]

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------------------
conv5_block7_concat (Concatenat (None, 4, 4, 736)    0
conv5_block6_concat[0][0]
conv5_block7_2_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv5_block8_0_bn (BatchNormali (None, 4, 4, 736)    2944
conv5_block7_concat[0][0]

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```
conv5_block8_0_relu (Activation (None, 4, 4, 736)    0
conv5_block8_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block8_1_conv (Conv2D)    (None, 4, 4, 128)    94208
conv5_block8_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block8_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block8_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block8_1_relu (Activation (None, 4, 4, 128)    0
conv5_block8_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block8_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block8_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block8_concat (Concatenat (None, 4, 4, 768)    0
conv5_block7_concat[0][0]
conv5_block8_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_0_bn (BatchNormali (None, 4, 4, 768)    3072
conv5_block8_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_0_relu (Activation (None, 4, 4, 768)    0
conv5_block9_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_1_conv (Conv2D)    (None, 4, 4, 128)    98304
conv5_block9_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_1_bn (BatchNormali (None, 4, 4, 128)    512
conv5_block9_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_1_relu (Activation (None, 4, 4, 128)    0
conv5_block9_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block9_2_conv (Conv2D)    (None, 4, 4, 32)     36864
conv5_block9_1_relu[0][0]
--------------------------------------------------------------------------------
```

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------------------
conv5_block9_concat (Concatenat (None, 4, 4, 800)    0
conv5_block8_concat[0][0]
conv5_block9_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_0_bn (BatchNormal (None, 4, 4, 800)    3200
conv5_block9_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_0_relu (Activatio (None, 4, 4, 800)    0
conv5_block10_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_1_conv (Conv2D)   (None, 4, 4, 128)    102400
conv5_block10_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block10_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block10_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block10_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block10_concat (Concatena (None, 4, 4, 832)    0
conv5_block9_concat[0][0]
conv5_block10_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_0_bn (BatchNormal (None, 4, 4, 832)    3328
conv5_block10_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_0_relu (Activatio (None, 4, 4, 832)    0
conv5_block11_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_1_conv (Conv2D)   (None, 4, 4, 128)    106496
conv5_block11_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block11_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block11_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block11_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block11_concat (Concatena (None, 4, 4, 864)    0
conv5_block10_concat[0][0]
conv5_block11_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_0_bn (BatchNormal (None, 4, 4, 864)    3456
conv5_block11_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_0_relu (Activatio (None, 4, 4, 864)    0
conv5_block12_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_1_conv (Conv2D)   (None, 4, 4, 128)    110592
conv5_block12_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block12_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block12_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block12_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block12_concat (Concatena (None, 4, 4, 896)    0
conv5_block11_concat[0][0]
conv5_block12_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block13_0_bn (BatchNormal (None, 4, 4, 896)    3584
conv5_block12_concat[0][0]
--------------------------------------------------------------------------------
```

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------------------
conv5_block13_0_relu (Activatio (None, 4, 4, 896)    0
conv5_block13_0_bn[0][0]
________________________________________________________________________________
------------------
conv5_block13_1_conv (Conv2D)   (None, 4, 4, 128)    114688
conv5_block13_0_relu[0][0]
________________________________________________________________________________
------------------
conv5_block13_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block13_1_conv[0][0]
________________________________________________________________________________
------------------
conv5_block13_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block13_1_bn[0][0]
________________________________________________________________________________
------------------
conv5_block13_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block13_1_relu[0][0]
________________________________________________________________________________
------------------
conv5_block13_concat (Concatena (None, 4, 4, 928)    0
conv5_block12_concat[0][0]
conv5_block13_2_conv[0][0]
________________________________________________________________________________
------------------
conv5_block14_0_bn (BatchNormal (None, 4, 4, 928)    3712
conv5_block13_concat[0][0]
________________________________________________________________________________
------------------
conv5_block14_0_relu (Activatio (None, 4, 4, 928)    0
conv5_block14_0_bn[0][0]
________________________________________________________________________________
------------------
conv5_block14_1_conv (Conv2D)   (None, 4, 4, 128)    118784
conv5_block14_0_relu[0][0]
________________________________________________________________________________
------------------
conv5_block14_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block14_1_conv[0][0]
________________________________________________________________________________
------------------
conv5_block14_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block14_1_bn[0][0]
________________________________________________________________________________
------------------
conv5_block14_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block14_1_relu[0][0]
```

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--------------------------------------------------------------------------------
------------------
conv5_block14_concat (Concatena (None, 4, 4, 960)    0
conv5_block13_concat[0][0]
conv5_block14_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_0_bn (BatchNormal (None, 4, 4, 960)    3840
conv5_block14_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_0_relu (Activatio (None, 4, 4, 960)    0
conv5_block15_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_1_conv (Conv2D)   (None, 4, 4, 128)    122880
conv5_block15_0_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block15_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block15_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block15_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block15_concat (Concatena (None, 4, 4, 992)    0
conv5_block14_concat[0][0]
conv5_block15_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_0_bn (BatchNormal (None, 4, 4, 992)    3968
conv5_block15_concat[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_0_relu (Activatio (None, 4, 4, 992)    0
conv5_block16_0_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_1_conv (Conv2D)   (None, 4, 4, 128)    126976
conv5_block16_0_relu[0][0]
--------------------------------------------------------------------------------
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```

```
conv5_block16_1_bn (BatchNormal (None, 4, 4, 128)    512
conv5_block16_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_1_relu (Activatio (None, 4, 4, 128)    0
conv5_block16_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_2_conv (Conv2D)   (None, 4, 4, 32)     36864
conv5_block16_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block16_concat (Concatena (None, 4, 4, 1024)   0
conv5_block15_concat[0][0]
conv5_block16_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
bn (BatchNormalization)         (None, 4, 4, 1024)   4096
conv5_block16_concat[0][0]
--------------------------------------------------------------------------------
------------------
relu (Activation)               (None, 4, 4, 1024)   0           bn[0][0]
--------------------------------------------------------------------------------
------------------
global_average_pooling2d (Globa (None, 1024)         0           relu[0][0]
--------------------------------------------------------------------------------
------------------
dense (Dense)                   (None, 1024)         1049600
global_average_pooling2d[0][0]
--------------------------------------------------------------------------------
------------------
dense_1 (Dense)                 (None, 2)            2050        dense[0][0]
================================================================================
==================
Total params: 8,089,154
Trainable params: 8,005,506
Non-trainable params: 83,648
--------------------------------------------------------------------------------
------------------
```

[4]:

```
# initialize the number of training epochs and batch size
NUM_EPOCHS = 50
BS = 32
TRAIN_PATH = '../dados/'
# determine the total number of image paths in training, validation,
# and testing directories
totalTrain = len(list(paths.list_images(TRAIN_PATH)))
```

[5]:

```
# initialize the training training data augmentation object
trainAug = ImageDataGenerator(
    rescale=1 / 255.0,
    rotation_range=20,
    zoom_range=0.05,
    width_shift_range=0.05,
    height_shift_range=0.05,
    shear_range=0.05,
    horizontal_flip=True,
    validation_split=0.1)
```

[6]:

```
# initialize the testing data augmentation object
testAug = ImageDataGenerator(rescale=1 / 255.0, validation_split=0.1)
```

[7]:

```
# initialize the training generator
trainGen = trainAug.flow_from_directory(
    TRAIN_PATH,
    class_mode="categorical",
    target_size=(height, width),
    color_mode="rgb",
    shuffle=True,
    seed=123,
    batch_size=BS,
    subset='training')
```

```
Found 3200 images belonging to 2 classes.
```

[8]:

```
# initialize the testing generator
testGen = testAug.flow_from_directory(
    TRAIN_PATH,
    class_mode="categorical",
    target_size=(height, width),
    color_mode="rgb",
    shuffle=False,
    batch_size=BS,
    subset='validation')
```

```
Found 355 images belonging to 2 classes.
```

[9]:

```
opt = SGD(lr=1e-1, momentum=0.9, decay=1e-1 / NUM_EPOCHS)
model.compile(loss="binary_crossentropy",
              optimizer=opt,
              metrics=["accuracy",
                       keras.metrics.AUC(),
                       keras.metrics.Precision(),
                       keras.metrics.Recall()])
```

[10]:

```
from PIL import Image, ImageFile
ImageFile.LOAD_TRUNCATED_IMAGES = True

# train our Keras model
H = model.fit(
    trainGen,
    validation_data=testGen,
    epochs=NUM_EPOCHS)
```

```
Epoch 1/50
100/100 [==============================] - 312s 3s/step - loss: 0.2858 -
accuracy: 0.9181 - auc: 0.9607 - precision: 0.9157 - recall: 0.9134 - val_loss:
76.0757 - val_accuracy: 0.4704 - val_auc: 0.4703 - val_precision: 0.4704 -
val_recall: 0.4704
Epoch 2/50
100/100 [==============================] - 315s 3s/step - loss: 0.1600 -
accuracy: 0.9453 - auc: 0.9842 - precision: 0.9430 - recall: 0.9463 - val_loss:
7.3658 - val_accuracy: 0.5352 - val_auc: 0.5729 - val_precision: 0.5352 -
val_recall: 0.5352
Epoch 3/50
100/100 [==============================] - 314s 3s/step - loss: 0.1178 -
accuracy: 0.9575 - auc: 0.9907 - precision: 0.9581 - recall: 0.9581 - val_loss:
0.2914 - val_accuracy: 0.8901 - val_auc: 0.9649 - val_precision: 0.8904 -
val_recall: 0.8930
Epoch 4/50
100/100 [==============================] - 309s 3s/step - loss: 0.1227 -
accuracy: 0.9588 - auc: 0.9898 - precision: 0.9588 - recall: 0.9588 - val_loss:
1.1698 - val_accuracy: 0.5859 - val_auc: 0.7714 - val_precision: 0.5859 -
val_recall: 0.5859
Epoch 5/50
100/100 [==============================] - 314s 3s/step - loss: 0.1087 -
accuracy: 0.9581 - auc: 0.9919 - precision: 0.9581 - recall: 0.9578 - val_loss:
0.8302 - val_accuracy: 0.6901 - val_auc: 0.8306 - val_precision: 0.6893 -
val_recall: 0.6873
Epoch 6/50
100/100 [==============================] - 305s 3s/step - loss: 0.1000 -
accuracy: 0.9638 - auc: 0.9929 - precision: 0.9638 - recall: 0.9641 - val_loss:
0.1643 - val_accuracy: 0.9296 - val_auc: 0.9838 - val_precision: 0.9296 -
val_recall: 0.9296
Epoch 7/50
100/100 [==============================] - 310s 3s/step - loss: 0.0921 -
accuracy: 0.9641 - auc: 0.9945 - precision: 0.9629 - recall: 0.9644 - val_loss:
0.6270 - val_accuracy: 0.8056 - val_auc: 0.8987 - val_precision: 0.8056 -
val_recall: 0.8056
Epoch 8/50
100/100 [==============================] - 309s 3s/step - loss: 0.0941 -
accuracy: 0.9691 - auc: 0.9941 - precision: 0.9691 - recall: 0.9691 - val_loss:
```

```
0.1644 - val_accuracy: 0.9380 - val_auc: 0.9847 - val_precision: 0.9380 -
val_recall: 0.9380
Epoch 9/50
100/100 [==============================] - 320s 3s/step - loss: 0.0894 -
accuracy: 0.9663 - auc: 0.9946 - precision: 0.9659 - recall: 0.9663 - val_loss:
0.1756 - val_accuracy: 0.9268 - val_auc: 0.9867 - val_precision: 0.9268 -
val_recall: 0.9268
Epoch 10/50
100/100 [==============================] - 317s 3s/step - loss: 0.0736 -
accuracy: 0.9716 - auc: 0.9962 - precision: 0.9710 - recall: 0.9719 - val_loss:
0.1534 - val_accuracy: 0.9437 - val_auc: 0.9870 - val_precision: 0.9437 -
val_recall: 0.9437
Epoch 11/50
100/100 [==============================] - 309s 3s/step - loss: 0.0790 -
accuracy: 0.9709 - auc: 0.9959 - precision: 0.9709 - recall: 0.9709 - val_loss:
0.1162 - val_accuracy: 0.9549 - val_auc: 0.9919 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 12/50
100/100 [==============================] - 315s 3s/step - loss: 0.0718 -
accuracy: 0.9725 - auc: 0.9962 - precision: 0.9725 - recall: 0.9725 - val_loss:
0.1600 - val_accuracy: 0.9324 - val_auc: 0.9845 - val_precision: 0.9324 -
val_recall: 0.9324
Epoch 13/50
100/100 [==============================] - 296s 3s/step - loss: 0.0781 -
accuracy: 0.9691 - auc: 0.9960 - precision: 0.9682 - recall: 0.9694 - val_loss:
0.1054 - val_accuracy: 0.9606 - val_auc: 0.9919 - val_precision: 0.9606 -
val_recall: 0.9606
Epoch 14/50
100/100 [==============================] - 291s 3s/step - loss: 0.0713 -
accuracy: 0.9737 - auc: 0.9964 - precision: 0.9741 - recall: 0.9737 - val_loss:
0.1194 - val_accuracy: 0.9521 - val_auc: 0.9906 - val_precision: 0.9521 -
val_recall: 0.9521
Epoch 15/50
100/100 [==============================] - 290s 3s/step - loss: 0.0738 -
accuracy: 0.9737 - auc: 0.9964 - precision: 0.9738 - recall: 0.9744 - val_loss:
0.1256 - val_accuracy: 0.9465 - val_auc: 0.9888 - val_precision: 0.9465 -
val_recall: 0.9465
Epoch 16/50
100/100 [==============================] - 289s 3s/step - loss: 0.0642 -
accuracy: 0.9756 - auc: 0.9973 - precision: 0.9756 - recall: 0.9753 - val_loss:
0.1280 - val_accuracy: 0.9577 - val_auc: 0.9883 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 17/50
100/100 [==============================] - 290s 3s/step - loss: 0.0668 -
accuracy: 0.9722 - auc: 0.9967 - precision: 0.9722 - recall: 0.9722 - val_loss:
0.1202 - val_accuracy: 0.9577 - val_auc: 0.9909 - val_precision: 0.9551 -
val_recall: 0.9577
Epoch 18/50
```

```
100/100 [==============================] - 291s 3s/step - loss: 0.0694 -
accuracy: 0.9741 - auc: 0.9962 - precision: 0.9741 - recall: 0.9737 - val_loss:
0.1004 - val_accuracy: 0.9465 - val_auc: 0.9938 - val_precision: 0.9463 -
val_recall: 0.9437
Epoch 19/50
100/100 [==============================] - 290s 3s/step - loss: 0.0665 -
accuracy: 0.9725 - auc: 0.9973 - precision: 0.9731 - recall: 0.9722 - val_loss:
0.1112 - val_accuracy: 0.9577 - val_auc: 0.9914 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 20/50
100/100 [==============================] - 290s 3s/step - loss: 0.0519 -
accuracy: 0.9812 - auc: 0.9978 - precision: 0.9819 - recall: 0.9816 - val_loss:
0.1567 - val_accuracy: 0.9634 - val_auc: 0.9844 - val_precision: 0.9634 -
val_recall: 0.9634
Epoch 21/50
100/100 [==============================] - 293s 3s/step - loss: 0.0659 -
accuracy: 0.9737 - auc: 0.9972 - precision: 0.9738 - recall: 0.9741 - val_loss:
0.1162 - val_accuracy: 0.9437 - val_auc: 0.9906 - val_precision: 0.9437 -
val_recall: 0.9437
Epoch 22/50
100/100 [==============================] - 291s 3s/step - loss: 0.0549 -
accuracy: 0.9759 - auc: 0.9979 - precision: 0.9750 - recall: 0.9759 - val_loss:
0.1445 - val_accuracy: 0.9549 - val_auc: 0.9889 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 23/50
100/100 [==============================] - 290s 3s/step - loss: 0.0646 -
accuracy: 0.9759 - auc: 0.9970 - precision: 0.9756 - recall: 0.9762 - val_loss:
0.0983 - val_accuracy: 0.9662 - val_auc: 0.9934 - val_precision: 0.9662 -
val_recall: 0.9662
Epoch 24/50
100/100 [==============================] - 302s 3s/step - loss: 0.0530 -
accuracy: 0.9787 - auc: 0.9983 - precision: 0.9781 - recall: 0.9787 - val_loss:
0.1002 - val_accuracy: 0.9634 - val_auc: 0.9927 - val_precision: 0.9634 -
val_recall: 0.9634
Epoch 25/50
100/100 [==============================] - 301s 3s/step - loss: 0.0492 -
accuracy: 0.9797 - auc: 0.9986 - precision: 0.9800 - recall: 0.9800 - val_loss:
0.1536 - val_accuracy: 0.9408 - val_auc: 0.9883 - val_precision: 0.9408 -
val_recall: 0.9408
Epoch 26/50
100/100 [==============================] - 296s 3s/step - loss: 0.0507 -
accuracy: 0.9797 - auc: 0.9984 - precision: 0.9797 - recall: 0.9797 - val_loss:
0.1217 - val_accuracy: 0.9549 - val_auc: 0.9917 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 27/50
100/100 [==============================] - 296s 3s/step - loss: 0.0506 -
accuracy: 0.9822 - auc: 0.9979 - precision: 0.9822 - recall: 0.9822 - val_loss:
0.1517 - val_accuracy: 0.9493 - val_auc: 0.9880 - val_precision: 0.9493 -
```

```
val_recall: 0.9493
Epoch 28/50
100/100 [==============================] - 306s 3s/step - loss: 0.0454 -
accuracy: 0.9822 - auc: 0.9988 - precision: 0.9822 - recall: 0.9822 - val_loss:
0.1461 - val_accuracy: 0.9408 - val_auc: 0.9887 - val_precision: 0.9408 -
val_recall: 0.9408
Epoch 29/50
100/100 [==============================] - 308s 3s/step - loss: 0.0478 -
accuracy: 0.9809 - auc: 0.9982 - precision: 0.9812 - recall: 0.9809 - val_loss:
0.1408 - val_accuracy: 0.9493 - val_auc: 0.9887 - val_precision: 0.9493 -
val_recall: 0.9493
Epoch 30/50
100/100 [==============================] - 267s 3s/step - loss: 0.0440 -
accuracy: 0.9819 - auc: 0.9988 - precision: 0.9819 - recall: 0.9828 - val_loss:
0.1645 - val_accuracy: 0.9493 - val_auc: 0.9855 - val_precision: 0.9493 -
val_recall: 0.9493
Epoch 31/50
100/100 [==============================] - 264s 3s/step - loss: 0.0469 -
accuracy: 0.9816 - auc: 0.9984 - precision: 0.9816 - recall: 0.9816 - val_loss:
0.1012 - val_accuracy: 0.9577 - val_auc: 0.9923 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 32/50
100/100 [==============================] - 262s 3s/step - loss: 0.0410 -
accuracy: 0.9853 - auc: 0.9987 - precision: 0.9856 - recall: 0.9853 - val_loss:
0.1120 - val_accuracy: 0.9577 - val_auc: 0.9924 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 33/50
100/100 [==============================] - 260s 3s/step - loss: 0.0418 -
accuracy: 0.9847 - auc: 0.9989 - precision: 0.9844 - recall: 0.9847 - val_loss:
0.1231 - val_accuracy: 0.9577 - val_auc: 0.9920 - val_precision: 0.9579 -
val_recall: 0.9606
Epoch 34/50
100/100 [==============================] - 289s 3s/step - loss: 0.0367 -
accuracy: 0.9844 - auc: 0.9989 - precision: 0.9844 - recall: 0.9847 - val_loss:
0.1311 - val_accuracy: 0.9577 - val_auc: 0.9899 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 35/50
100/100 [==============================] - 316s 3s/step - loss: 0.0363 -
accuracy: 0.9853 - auc: 0.9992 - precision: 0.9853 - recall: 0.9859 - val_loss:
0.1331 - val_accuracy: 0.9493 - val_auc: 0.9901 - val_precision: 0.9494 -
val_recall: 0.9521
Epoch 36/50
100/100 [==============================] - 297s 3s/step - loss: 0.0436 -
accuracy: 0.9841 - auc: 0.9984 - precision: 0.9844 - recall: 0.9841 - val_loss:
0.1927 - val_accuracy: 0.9549 - val_auc: 0.9809 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 37/50
100/100 [==============================] - 294s 3s/step - loss: 0.0441 -
```

```
accuracy: 0.9825 - auc: 0.9988 - precision: 0.9822 - recall: 0.9822 - val_loss:
0.1278 - val_accuracy: 0.9493 - val_auc: 0.9909 - val_precision: 0.9493 -
val_recall: 0.9493
Epoch 38/50
100/100 [==============================] - 288s 3s/step - loss: 0.0364 -
accuracy: 0.9862 - auc: 0.9989 - precision: 0.9862 - recall: 0.9862 - val_loss:
0.2655 - val_accuracy: 0.9099 - val_auc: 0.9647 - val_precision: 0.9099 -
val_recall: 0.9099
Epoch 39/50
100/100 [==============================] - 292s 3s/step - loss: 0.0319 -
accuracy: 0.9862 - auc: 0.9994 - precision: 0.9862 - recall: 0.9862 - val_loss:
0.1682 - val_accuracy: 0.9493 - val_auc: 0.9869 - val_precision: 0.9493 -
val_recall: 0.9493
Epoch 40/50
100/100 [==============================] - 290s 3s/step - loss: 0.0349 -
accuracy: 0.9856 - auc: 0.9993 - precision: 0.9856 - recall: 0.9859 - val_loss:
0.3203 - val_accuracy: 0.9183 - val_auc: 0.9634 - val_precision: 0.9183 -
val_recall: 0.9183
Epoch 41/50
100/100 [==============================] - 289s 3s/step - loss: 0.0355 -
accuracy: 0.9862 - auc: 0.9992 - precision: 0.9862 - recall: 0.9862 - val_loss:
0.1140 - val_accuracy: 0.9521 - val_auc: 0.9914 - val_precision: 0.9521 -
val_recall: 0.9521
Epoch 42/50
100/100 [==============================] - 292s 3s/step - loss: 0.0323 -
accuracy: 0.9869 - auc: 0.9994 - precision: 0.9869 - recall: 0.9875 - val_loss:
0.1447 - val_accuracy: 0.9408 - val_auc: 0.9878 - val_precision: 0.9408 -
val_recall: 0.9408
Epoch 43/50
100/100 [==============================] - 326s 3s/step - loss: 0.0276 -
accuracy: 0.9872 - auc: 0.9995 - precision: 0.9872 - recall: 0.9872 - val_loss:
0.1396 - val_accuracy: 0.9465 - val_auc: 0.9890 - val_precision: 0.9465 -
val_recall: 0.9465
Epoch 44/50
100/100 [==============================] - 311s 3s/step - loss: 0.0303 -
accuracy: 0.9878 - auc: 0.9992 - precision: 0.9875 - recall: 0.9878 - val_loss:
0.1664 - val_accuracy: 0.9296 - val_auc: 0.9868 - val_precision: 0.9296 -
val_recall: 0.9296
Epoch 45/50
100/100 [==============================] - 290s 3s/step - loss: 0.0357 -
accuracy: 0.9869 - auc: 0.9992 - precision: 0.9869 - recall: 0.9866 - val_loss:
0.1381 - val_accuracy: 0.9577 - val_auc: 0.9923 - val_precision: 0.9577 -
val_recall: 0.9577
Epoch 46/50
100/100 [==============================] - 289s 3s/step - loss: 0.0235 -
accuracy: 0.9925 - auc: 0.9994 - precision: 0.9928 - recall: 0.9925 - val_loss:
0.1251 - val_accuracy: 0.9577 - val_auc: 0.9916 - val_precision: 0.9577 -
val_recall: 0.9577
```

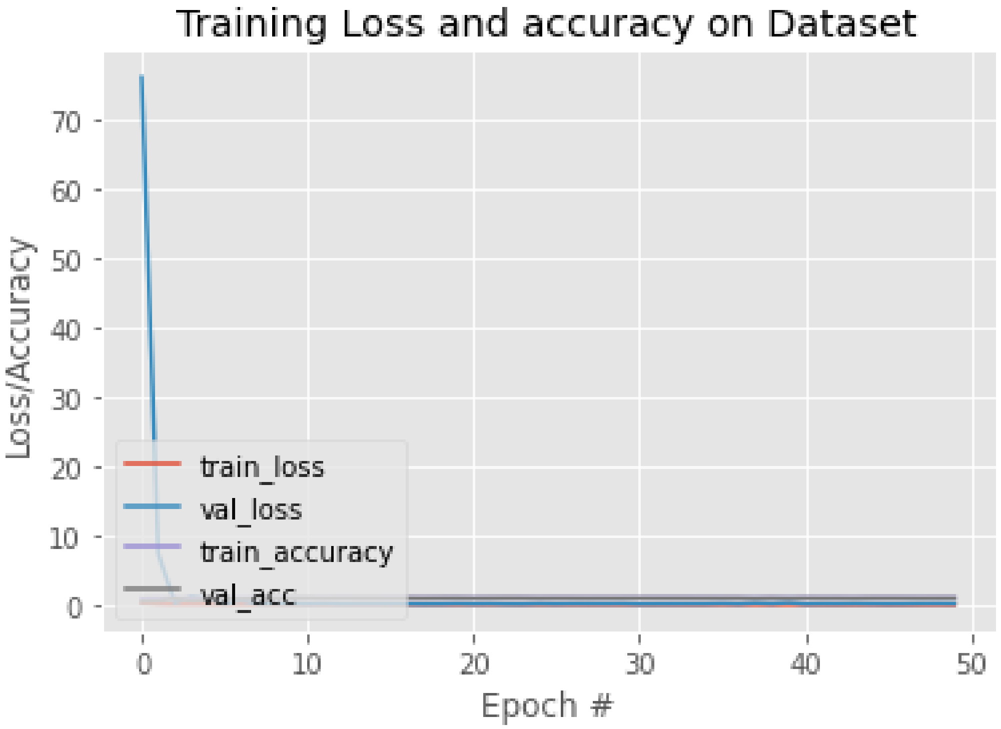
```
Epoch 47/50
100/100 [==============================] - 290s 3s/step - loss: 0.0266 -
accuracy: 0.9903 - auc: 0.9993 - precision: 0.9903 - recall: 0.9894 - val_loss:
0.1388 - val_accuracy: 0.9549 - val_auc: 0.9876 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 48/50
100/100 [==============================] - 287s 3s/step - loss: 0.0264 -
accuracy: 0.9906 - auc: 0.9991 - precision: 0.9906 - recall: 0.9906 - val_loss:
0.1679 - val_accuracy: 0.9493 - val_auc: 0.9854 - val_precision: 0.9493 -
val_recall: 0.9493
Epoch 49/50
100/100 [==============================] - 289s 3s/step - loss: 0.0319 -
accuracy: 0.9869 - auc: 0.9994 - precision: 0.9869 - recall: 0.9869 - val_loss:
0.1769 - val_accuracy: 0.9549 - val_auc: 0.9818 - val_precision: 0.9549 -
val_recall: 0.9549
Epoch 50/50
100/100 [==============================] - 288s 3s/step - loss: 0.0216 -
accuracy: 0.9906 - auc: 0.9997 - precision: 0.9906 - recall: 0.9906 - val_loss:
0.1664 - val_accuracy: 0.9606 - val_auc: 0.9849 - val_precision: 0.9606 -
val_recall: 0.9606
```

[11]:

```python
import matplotlib.pyplot as plt

N = NUM_EPOCHS
plt.style.use("ggplot")
plt.figure()
plt.plot(np.arange(0, N), H.history["loss"], label="train_loss")
plt.plot(np.arange(0, N), H.history["val_loss"], label="val_loss")

plt.plot(np.arange(0, N), H.history["accuracy"], label="train_accuracy")
plt.plot(np.arange(0, N), H.history["val_accuracy"], label="val_acc")
plt.title("Training Loss and accuracy on Dataset")
plt.xlabel("Epoch #")
plt.ylabel("Loss/Accuracy")
plt.legend(loc="lower left")
plt.savefig('Training Loss and accuracy on Dataset')
H.history.keys()
```

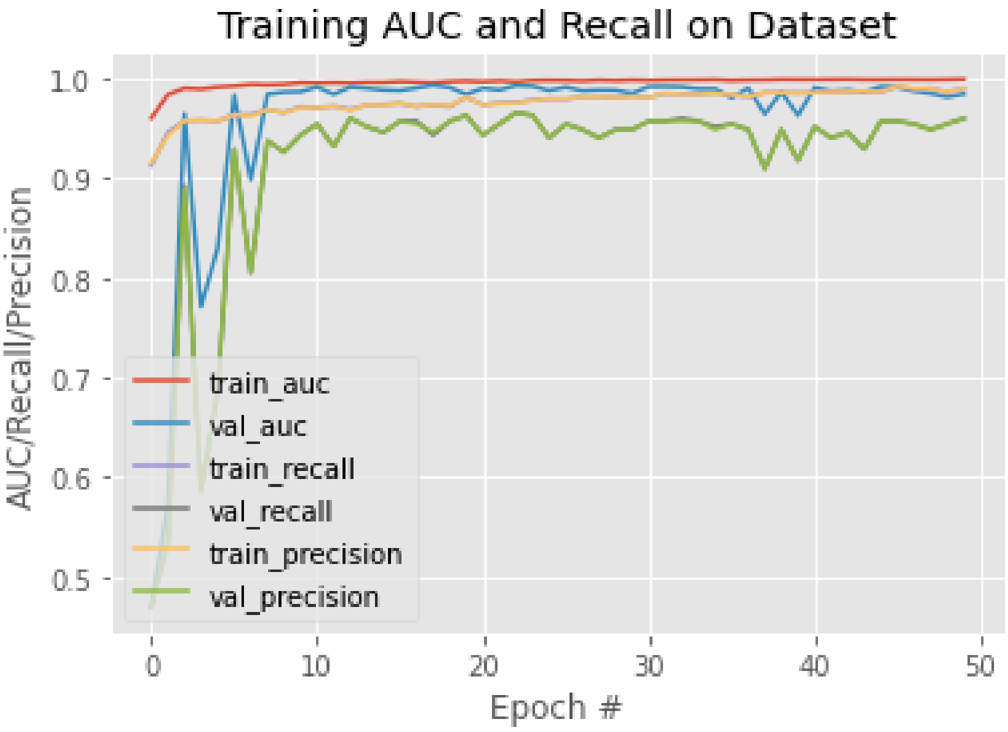
[11]:

```
dict_keys(['loss', 'accuracy', 'auc', 'precision', 'recall', 'val_loss',
'val_accuracy', 'val_auc', 'val_precision', 'val_recall'])
```



[12]:

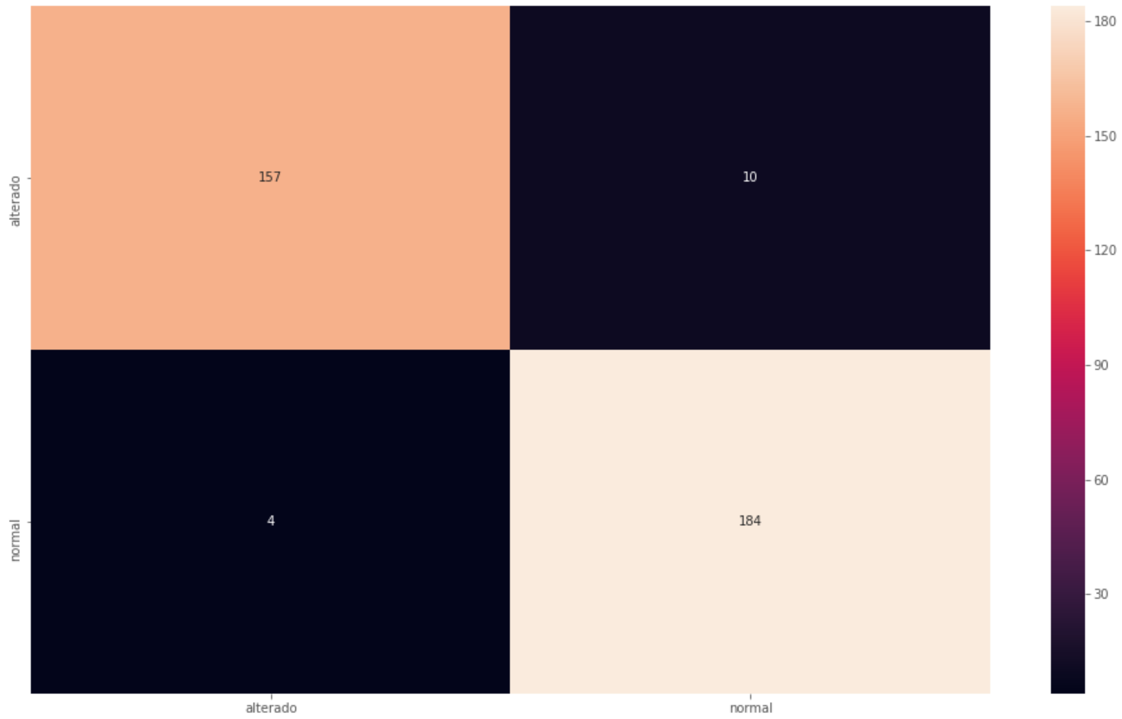
```
plt.style.use("ggplot")
plt.figure()
plt.plot(np.arange(0, N), H.history["auc"], label="train_auc")
plt.plot(np.arange(0, N), H.history["val_auc"], label="val_auc")
plt.plot(np.arange(0, N), H.history["recall"], label="train_recall")
plt.plot(np.arange(0, N), H.history["val_recall"], label="val_recall")
plt.plot(np.arange(0, N), H.history["precision"], label="train_precision")
plt.plot(np.arange(0, N), H.history["val_precision"], label="val_precision")

plt.title("Training AUC and Recall on Dataset")
plt.xlabel("Epoch #")
plt.ylabel("AUC/Recall/Precision")
plt.legend(loc="lower left")
plt.savefig('Training AUC, Recall and Precision on Dataset')
```



[13]:

```
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix
import pandas as pd
import seaborn as sns

testGen.reset()
predIdxs = model.predict(testGen, batch_size=BS)

# for each image in the testing set we need to find the index of the
# label with corresponding largest predicted probability
predIdxs = np.argmax(predIdxs, axis=1)


conf_mat = confusion_matrix(testGen.classes, predIdxs)

class_names = ['alterado', 'normal']
fig = plt.figure(figsize=(17,10))
df_cm = pd.DataFrame(conf_mat, index=class_names, columns=class_names)
heatmap = sns.heatmap(df_cm, annot=True, fmt='d')
heatmap

# show a nicely formatted classification report
print(classification_report(testGen.classes, predIdxs,
                            target_names=testGen.class_indices.keys()))
```

```
                     precision    recall  f1-score   support

rx-alterado-anonim       0.98      0.94      0.96       167
  rx-normal-anonim       0.95      0.98      0.96       188

          accuracy                           0.96       355
         macro avg       0.96      0.96      0.96       355
      weighted avg       0.96      0.96      0.96       355
```



```
[14]: model.save('Models/DenseNet121_H{}W{}.h5'.format(height, width))
```