# DenseNet121 - TB

October 27, 2023

[ ]:

```python
# importing packages
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
%matplotlib inline
import datetime

import warnings
warnings.simplefilter("ignore")

import tensorflow as tf
from keras import Model
from keras.models import Model
from keras.models import load_model, save_model
from keras.layers import Dense, Dropout, Flatten, AveragePooling2D
from keras.preprocessing.image import ImageDataGenerator
from keras.optimizers import Adam
from keras.callbacks import ModelCheckpoint, CSVLogger, ReduceLROnPlateau, TensorBoard
from keras.metrics import AUC, Precision, Recall
from keras.applications import DenseNet121

from sklearn.metrics import confusion_matrix, roc_curve, auc, precision_recall_curve
from sklearn.utils import class_weight

import os

from utils import *

%reload_ext autoreload
%autoreload 2
```

[ ]:

```python
# defining parameters
IMAGE_SIZE = 224
BATCH_SIZE = 32
```

```
INIT_LR = 0.001
EPOCHS = 20
```

## 0.1 Set up the file directory and image paths

[ ]:

```
# Set path for training testing and validation
# Data Generator for training, validation, and testing

folder = '../data/augmented_sorted'

# assigning paths
src_path_train = os.path.join(folder, 'train/')
src_path_val = os.path.join(folder, "val/")
src_path_test = os.path.join(folder,  'test/')

train_generator = ImageDataGenerator(rescale=1./255).flow_from_directory(
        src_path_train,
        target_size = (IMAGE_SIZE, IMAGE_SIZE),
        batch_size = BATCH_SIZE,
        class_mode = 'binary',
        shuffle = True,
        seed = 42)
valid_generator = ImageDataGenerator(rescale=1./255).flow_from_directory(
        src_path_val,
        target_size = (IMAGE_SIZE, IMAGE_SIZE),
        batch_size = BATCH_SIZE,
        class_mode = 'binary',
        shuffle = True,
        seed = 42)
test_generator = ImageDataGenerator(rescale=1./255).flow_from_directory(
        src_path_test,
        target_size = (IMAGE_SIZE, IMAGE_SIZE),
        batch_size = 1,
        class_mode = None,
        shuffle = False,
        seed = 42)

STEP_SIZE_TRAIN = train_generator.n // train_generator.batch_size
STEP_SIZE_VALID = valid_generator.n // valid_generator.batch_size
STEP_SIZE_TEST = test_generator.n // test_generator.batch_size
```

```
Found 10134 images belonging to 2 classes.
Found 1031 images belonging to 2 classes.
Found 1035 images belonging to 2 classes.
```

[ ]:

```
# calculate class weights
total_tb = len(os.listdir(os.path.join(src_path_train, 'TB')))
```

```
total_healthy = len(os.listdir(os.path.join(src_path_train, 'Non-TB')))

weight_for_0 = total_tb / (total_healthy + total_tb)
weight_for_1 = total_healthy / (total_healthy + total_tb)

class_weights = {0: weight_for_0, 1: weight_for_1}
class_weights
```

[ ]:

```
{0: 0.36895598973751725, 1: 0.6310440102624827}
```

[ ]:

```
# create model
def build_DenseNet_model():
    baseModel = DenseNet121(weights="imagenet",
                            include_top=False,
                            input_tensor=Input(shape=(IMAGE_SIZE, IMAGE_SIZE,␣
 ↪3)))
    output = baseModel.output
    output = AveragePooling2D(pool_size=(2, 2))(output)
    output = Flatten(name="flatten")(output)
    output = Dense(512, activation="relu")(output)
    output = Dropout(0.25)(output)
    output = Dense(1, activation="sigmoid")(output)
    model = Model(inputs=baseModel.input, outputs=output)
    for layer in baseModel.layers:
        layer.trainable = False
    return model


model = build_DenseNet_model()

MODEL_NAME = 'DenseNet'
model_path = os.path.join("logs", MODEL_NAME)

try:
    if not os.path.exists(model_path):
        os.makedirs(model_path)
        print("Model Directory Created")
    else:
        files = glob(os.path.join(model_path, "*"))
        for f in files:
            os.remove(f)
        print("Model Directory Already Exists and Files Deleted")
except Exception as e:
    print('Failed to delete %s. Reason: %s' % (model_path, e))


# compile model
```

```
model.compile(
    loss="binary_crossentropy",
    optimizer=tf.keras.optimizers.legacy.Adam(
        learning_rate=INIT_LR, decay=INIT_LR / EPOCHS
    ),
    metrics=["accuracy", AUC(), AUC(curve="PR"), Precision(), Recall()],
)
```

[ ]:

```
# define callback
# es = EarlyStopping(monitor = 'val_loss',
    #               verbose = 1,
    #               mode = 'min',
    #               patience = 4),
rlrp = ReduceLROnPlateau(monitor="val_accuracy",
                      patience=3,
                      verbose=1,
                      factor=0.5,
                      min_lr=0.00001)
mcp = ModelCheckpoint(filepath=os.path.join(model_path, "checkpoints/
 ↪model_{epoch:02d}_{val_loss:.2f}.hdf5"),
                    verbose=1,
                    monitor="val_loss",
                    mode="min")
cl = CSVLogger(os.path.join(model_path, "log.csv"))
tb = TensorBoard(log_dir=os.path.join(model_path, "tb_log"),
                 histogram_freq=1,
                 update_freq="batch")

# train model
history = model.fit(train_generator,
                    steps_per_epoch = STEP_SIZE_TRAIN,
                    validation_data = valid_generator,
                    validation_steps = STEP_SIZE_VALID,
                    epochs = EPOCHS,
                    class_weight = class_weights,
                    callbacks = [rlrp, mcp, cl, tb])
```

```
Model Directory Already Exists
```

[ ]:

```
# train model
history = model.fit(train_generator,
                    steps_per_epoch = STEP_SIZE_TRAIN,
                    validation_data = valid_generator,
                    validation_steps = STEP_SIZE_VALID,
                    epochs = EPOCHS,
                    class_weight = class_weights,
                     callbacks = [mcp_save, lr_reduction, csv_logger,␣
↪tensorboard_cb])
```

```
Epoch 1/20
633/633 [==============================] - ETA: 0s - loss: 0.1256 - accuracy:
0.9067 - auc: 0.9623 - auc_1: 0.9457 - precision: 0.8608 - recall: 0.8912
Epoch 1: saving model to logs/log_densenet/model.01-0.15.hdf5
633/633 [==============================] - 362s 565ms/step - loss: 0.1256 -
accuracy: 0.9067 - auc: 0.9623 - auc_1: 0.9457 - precision: 0.8608 - recall:
0.8912 - val_loss: 0.1487 - val_accuracy: 0.9502 - val_auc: 0.9831 - val_auc_1:
0.9583 - val_precision: 0.8719 - val_recall: 0.9134 - lr: 0.0010
Epoch 2/20
633/633 [==============================] - ETA: 0s - loss: 0.0651 - accuracy:
0.9445 - auc: 0.9877 - auc_1: 0.9822 - precision: 0.9150 - recall: 0.9366
Epoch 2: saving model to logs/log_densenet/model.02-0.15.hdf5
633/633 [==============================] - 354s 559ms/step - loss: 0.0651 -
accuracy: 0.9445 - auc: 0.9877 - auc_1: 0.9822 - precision: 0.9150 - recall:
0.9366 - val_loss: 0.1511 - val_accuracy: 0.9414 - val_auc: 0.9813 - val_auc_1:
0.9594 - val_precision: 0.9340 - val_recall: 0.7965 - lr: 0.0010
Epoch 3/20
633/633 [==============================] - ETA: 0s - loss: 0.0523 - accuracy:
0.9572 - auc: 0.9918 - auc_1: 0.9881 - precision: 0.9349 - recall: 0.9502
Epoch 3: saving model to logs/log_densenet/model.03-0.12.hdf5
633/633 [==============================] - 327s 517ms/step - loss: 0.0523 -
accuracy: 0.9572 - auc: 0.9918 - auc_1: 0.9881 - precision: 0.9349 - recall:
0.9502 - val_loss: 0.1167 - val_accuracy: 0.9570 - val_auc: 0.9872 - val_auc_1:
0.9701 - val_precision: 0.8816 - val_recall: 0.9351 - lr: 0.0010
Epoch 4/20
633/633 [==============================] - ETA: 0s - loss: 0.0445 - accuracy:
0.9618 - auc: 0.9939 - auc_1: 0.9907 - precision: 0.9391 - recall: 0.9585
Epoch 4: saving model to logs/log_densenet/model.04-0.10.hdf5
633/633 [==============================] - 329s 519ms/step - loss: 0.0445 -
accuracy: 0.9618 - auc: 0.9939 - auc_1: 0.9907 - precision: 0.9391 - recall:
0.9585 - val_loss: 0.1025 - val_accuracy: 0.9619 - val_auc: 0.9879 - val_auc_1:
0.9736 - val_precision: 0.9283 - val_recall: 0.9000 - lr: 0.0010
Epoch 5/20
633/633 [==============================] - ETA: 0s - loss: 0.0415 - accuracy:
0.9649 - auc: 0.9948 - auc_1: 0.9920 - precision: 0.9440 - recall: 0.9620
Epoch 5: saving model to logs/log_densenet/model.05-0.10.hdf5
633/633 [==============================] - 332s 524ms/step - loss: 0.0415 -
accuracy: 0.9649 - auc: 0.9948 - auc_1: 0.9920 - precision: 0.9440 - recall:
0.9620 - val_loss: 0.1003 - val_accuracy: 0.9639 - val_auc: 0.9896 - val_auc_1:
0.9754 - val_precision: 0.9079 - val_recall: 0.9353 - lr: 0.0010
Epoch 6/20
633/633 [==============================] - ETA: 0s - loss: 0.0317 - accuracy:
0.9740 - auc: 0.9969 - auc_1: 0.9944 - precision: 0.9580 - recall: 0.9722
Epoch 6: saving model to logs/log_densenet/model.06-0.11.hdf5
633/633 [==============================] - 332s 524ms/step - loss: 0.0317 -
```

```
accuracy: 0.9740 - auc: 0.9969 - auc_1: 0.9944 - precision: 0.9580 - recall:
0.9722 - val_loss: 0.1092 - val_accuracy: 0.9648 - val_auc: 0.9887 - val_auc_1:
0.9746 - val_precision: 0.9493 - val_recall: 0.8918 - lr: 0.0010
Epoch 7/20
633/633 [==============================] - ETA: 0s - loss: 0.0262 - accuracy:
0.9774 - auc: 0.9978 - auc_1: 0.9960 - precision: 0.9620 - recall: 0.9772
Epoch 7: saving model to logs/log_densenet/model.07-0.09.hdf5
633/633 [==============================] - 339s 535ms/step - loss: 0.0262 -
accuracy: 0.9774 - auc: 0.9978 - auc_1: 0.9960 - precision: 0.9620 - recall:
0.9772 - val_loss: 0.0899 - val_accuracy: 0.9629 - val_auc: 0.9914 - val_auc_1:
0.9750 - val_precision: 0.9106 - val_recall: 0.9264 - lr: 0.0010
Epoch 8/20
633/633 [==============================] - ETA: 0s - loss: 0.0256 - accuracy:
0.9780 - auc: 0.9979 - auc_1: 0.9965 - precision: 0.9641 - recall: 0.9767
Epoch 8: saving model to logs/log_densenet/model.08-0.14.hdf5
633/633 [==============================] - 349s 551ms/step - loss: 0.0256 -
accuracy: 0.9780 - auc: 0.9979 - auc_1: 0.9965 - precision: 0.9641 - recall:
0.9767 - val_loss: 0.1369 - val_accuracy: 0.9561 - val_auc: 0.9896 - val_auc_1:
0.9669 - val_precision: 0.8577 - val_recall: 0.9654 - lr: 0.0010
Epoch 9/20
633/633 [==============================] - ETA: 0s - loss: 0.0244 - accuracy:
0.9807 - auc: 0.9979 - auc_1: 0.9962 - precision: 0.9695 - recall: 0.9786
Epoch 9: saving model to logs/log_densenet/model.09-0.11.hdf5

Epoch 9: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.
633/633 [==============================] - 341s 539ms/step - loss: 0.0244 -
accuracy: 0.9807 - auc: 0.9979 - auc_1: 0.9962 - precision: 0.9695 - recall:
0.9786 - val_loss: 0.1134 - val_accuracy: 0.9600 - val_auc: 0.9879 - val_auc_1:
0.9759 - val_precision: 0.9567 - val_recall: 0.8615 - lr: 0.0010
Epoch 10/20
633/633 [==============================] - ETA: 0s - loss: 0.0134 - accuracy:
0.9895 - auc: 0.9995 - auc_1: 0.9989 - precision: 0.9837 - recall: 0.9879
Epoch 10: saving model to logs/log_densenet/model.10-0.10.hdf5
633/633 [==============================] - 354s 559ms/step - loss: 0.0134 -
accuracy: 0.9895 - auc: 0.9995 - auc_1: 0.9989 - precision: 0.9837 - recall:
0.9879 - val_loss: 0.1030 - val_accuracy: 0.9668 - val_auc: 0.9914 - val_auc_1:
0.9733 - val_precision: 0.9020 - val_recall: 0.9567 - lr: 5.0000e-04
Epoch 11/20
633/633 [==============================] - ETA: 0s - loss: 0.0102 - accuracy:
0.9917 - auc: 0.9997 - auc_1: 0.9993 - precision: 0.9880 - recall: 0.9896
Epoch 11: saving model to logs/log_densenet/model.11-0.10.hdf5
633/633 [==============================] - 336s 530ms/step - loss: 0.0102 -
accuracy: 0.9917 - auc: 0.9997 - auc_1: 0.9993 - precision: 0.9880 - recall:
0.9896 - val_loss: 0.0980 - val_accuracy: 0.9697 - val_auc: 0.9899 - val_auc_1:
0.9820 - val_precision: 0.9718 - val_recall: 0.8922 - lr: 5.0000e-04
Epoch 12/20
633/633 [==============================] - ETA: 0s - loss: 0.0097 - accuracy:
0.9924 - auc: 0.9998 - auc_1: 0.9996 - precision: 0.9880 - recall: 0.9914
```

```
Epoch 12: saving model to logs/log_densenet/model.12-0.10.hdf5
633/633 [==============================] - 353s 556ms/step - loss: 0.0097 -
accuracy: 0.9924 - auc: 0.9998 - auc_1: 0.9996 - precision: 0.9880 - recall:
0.9914 - val_loss: 0.0995 - val_accuracy: 0.9707 - val_auc: 0.9886 - val_auc_1:
0.9723 - val_precision: 0.9427 - val_recall: 0.9264 - lr: 5.0000e-04
Epoch 13/20
633/633 [==============================] - ETA: 0s - loss: 0.0091 - accuracy:
0.9922 - auc: 0.9997 - auc_1: 0.9994 - precision: 0.9872 - recall: 0.9917
Epoch 13: saving model to logs/log_densenet/model.13-0.12.hdf5
633/633 [==============================] - 336s 531ms/step - loss: 0.0091 -
accuracy: 0.9922 - auc: 0.9997 - auc_1: 0.9994 - precision: 0.9872 - recall:
0.9917 - val_loss: 0.1159 - val_accuracy: 0.9688 - val_auc: 0.9903 - val_auc_1:
0.9741 - val_precision: 0.9032 - val_recall: 0.9655 - lr: 5.0000e-04
Epoch 14/20
633/633 [==============================] - ETA: 0s - loss: 0.0064 - accuracy:
0.9955 - auc: 0.9999 - auc_1: 0.9998 - precision: 0.9933 - recall: 0.9944
Epoch 14: saving model to logs/log_densenet/model.14-0.13.hdf5
633/633 [==============================] - 339s 536ms/step - loss: 0.0064 -
accuracy: 0.9955 - auc: 0.9999 - auc_1: 0.9998 - precision: 0.9933 - recall:
0.9944 - val_loss: 0.1262 - val_accuracy: 0.9678 - val_auc: 0.9878 - val_auc_1:
0.9677 - val_precision: 0.9046 - val_recall: 0.9561 - lr: 5.0000e-04
Epoch 15/20
633/633 [==============================] - ETA: 0s - loss: 0.0057 - accuracy:
0.9951 - auc: 0.9999 - auc_1: 0.9999 - precision: 0.9915 - recall: 0.9952
Epoch 15: saving model to logs/log_densenet/model.15-0.12.hdf5

Epoch 15: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.
633/633 [==============================] - 343s 541ms/step - loss: 0.0057 -
accuracy: 0.9951 - auc: 0.9999 - auc_1: 0.9999 - precision: 0.9915 - recall:
0.9952 - val_loss: 0.1233 - val_accuracy: 0.9658 - val_auc: 0.9863 - val_auc_1:
0.9722 - val_precision: 0.9372 - val_recall: 0.9087 - lr: 5.0000e-04
Epoch 16/20
633/633 [==============================] - ETA: 0s - loss: 0.0033 - accuracy:
0.9983 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9979 - recall: 0.9976
Epoch 16: saving model to logs/log_densenet/model.16-0.11.hdf5
633/633 [==============================] - 347s 548ms/step - loss: 0.0033 -
accuracy: 0.9983 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9979 - recall:
0.9976 - val_loss: 0.1061 - val_accuracy: 0.9717 - val_auc: 0.9892 - val_auc_1:
0.9744 - val_precision: 0.9280 - val_recall: 0.9481 - lr: 2.5000e-04
Epoch 17/20
633/633 [==============================] - ETA: 0s - loss: 0.0034 - accuracy:
0.9977 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9960 - recall: 0.9979
Epoch 17: saving model to logs/log_densenet/model.17-0.12.hdf5
633/633 [==============================] - 344s 542ms/step - loss: 0.0034 -
accuracy: 0.9977 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9960 - recall:
0.9979 - val_loss: 0.1192 - val_accuracy: 0.9668 - val_auc: 0.9879 - val_auc_1:
0.9674 - val_precision: 0.9195 - val_recall: 0.9353 - lr: 2.5000e-04
Epoch 18/20
```

```
633/633 [==============================] - ETA: 0s - loss: 0.0029 - accuracy:
0.9977 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9963 - recall: 0.9976
Epoch 18: saving model to logs/log_densenet/model.18-0.12.hdf5
633/633 [==============================] - 346s 547ms/step - loss: 0.0029 -
accuracy: 0.9977 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9963 - recall:
0.9976 - val_loss: 0.1242 - val_accuracy: 0.9707 - val_auc: 0.9856 - val_auc_1:
0.9621 - val_precision: 0.9351 - val_recall: 0.9351 - lr: 2.5000e-04
Epoch 19/20
633/633 [==============================] - ETA: 0s - loss: 0.0029 - accuracy:
0.9981 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9971 - recall: 0.9979
Epoch 19: saving model to logs/log_densenet/model.19-0.15.hdf5

Epoch 19: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.
633/633 [==============================] - 342s 540ms/step - loss: 0.0029 -
accuracy: 0.9981 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9971 - recall:
0.9979 - val_loss: 0.1500 - val_accuracy: 0.9678 - val_auc: 0.9868 - val_auc_1:
0.9579 - val_precision: 0.8964 - val_recall: 0.9698 - lr: 2.5000e-04
Epoch 20/20
633/633 [==============================] - ETA: 0s - loss: 0.0019 - accuracy:
0.9989 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9981 - recall: 0.9989
Epoch 20: saving model to logs/log_densenet/model.20-0.13.hdf5
633/633 [==============================] - 339s 535ms/step - loss: 0.0019 -
accuracy: 0.9989 - auc: 1.0000 - auc_1: 1.0000 - precision: 0.9981 - recall:
0.9989 - val_loss: 0.1250 - val_accuracy: 0.9688 - val_auc: 0.9879 - val_auc_1:
0.9647 - val_precision: 0.9237 - val_recall: 0.9397 - lr: 1.2500e-04
```

[ ]:

```
save_model(
    model,
    os.path.join(model_path, "DenseNet-model.h5"),
    overwrite=True,
    include_optimizer=True,
    save_format=None,
    signatures=None,
    options=None,
)

model.save(os.path.join(model_path, "DenseNet-model.keras"))
model.save_weights(os.path.join(model_path, "DenseNet-weights.h5"))
```

[ ]:

```
history = pd.read_csv('../modeling/logs/log_densenet/log.csv')
history
```

[ ]:

```
   epoch  accuracy       auc     auc_1      loss        lr  precision  \
0      0  0.906701  0.962340  0.945699  0.125611  0.001000   0.860802
1      1  0.944455  0.987723  0.982215  0.065120  0.001000   0.915010
2      2  0.957205  0.991761  0.988055  0.052331  0.001000   0.934897
3      3  0.961751  0.993941  0.990686  0.044471  0.001000   0.939076
```

```
4       4  0.964914  0.994751  0.991971  0.041460  0.001000   0.943992
5       5  0.974007  0.996855  0.994440  0.031731  0.001000   0.958048
6       6  0.977367  0.997792  0.996037  0.026191  0.001000   0.962025
7       7  0.977960  0.997851  0.996501  0.025550  0.001000   0.964059
8       8  0.980727  0.997926  0.996187  0.024361  0.001000   0.969496
9       9  0.989524  0.999453  0.998934  0.013442  0.000500   0.983725
10     10  0.991698  0.999683  0.999315  0.010221  0.000500   0.987971
11     11  0.992390  0.999762  0.999601  0.009712  0.000500   0.987987
12     12  0.992192  0.999710  0.999364  0.009081  0.000500   0.987200
13     13  0.995454  0.999903  0.999837  0.006359  0.000500   0.993312
14     14  0.995058  0.999929  0.999880  0.005721  0.000500   0.991469
15     15  0.998320  0.999980  0.999966  0.003341  0.000250   0.997857
16     16  0.997727  0.999969  0.999950  0.003372  0.000250   0.995993
17     17  0.997727  0.999986  0.999977  0.002939  0.000250   0.996256
18     18  0.998122  0.999974  0.999957  0.002904  0.000250   0.997055
19     19  0.998913  0.999997  0.999994  0.001863  0.000125   0.998126

      recall  val_accuracy   val_auc  val_auc_1  val_loss  val_precision  \
0   0.891240      0.950195  0.983072   0.958303  0.148746       0.871901
1   0.936563      0.941406  0.981347   0.959384  0.151120       0.934010
2   0.950174      0.957031  0.987196   0.970079  0.116735       0.881633
3   0.958456      0.961914  0.987852   0.973631  0.102534       0.928251
4   0.961951      0.963867  0.989581   0.975364  0.100319       0.907950
5   0.972155      0.964844  0.988686   0.974554  0.109166       0.949309
6   0.977230      0.962891  0.991413   0.975030  0.089883       0.910638
7   0.976707      0.956055  0.989620   0.966939  0.136893       0.857692
8   0.978581      0.959961  0.987911   0.975862  0.113446       0.956731
9   0.987942      0.966797  0.991437   0.973296  0.102957       0.902041
10  0.989558      0.969727  0.989948   0.981984  0.098030       0.971831
11  0.991428      0.970703  0.988604   0.972262  0.099540       0.942731
12  0.991696      0.968750  0.990299   0.974052  0.115864       0.903226
13  0.994376      0.967773  0.987823   0.967668  0.126166       0.904564
14  0.995183      0.965820  0.986272   0.972221  0.123338       0.937220
15  0.997590      0.971680  0.989246   0.974431  0.106107       0.927966
16  0.997859      0.966797  0.987880   0.967391  0.119166       0.919492
17  0.997590      0.970703  0.985580   0.962120  0.124185       0.935065
18  0.997856      0.967773  0.986767   0.957902  0.150025       0.896414
19  0.998928      0.968750  0.987872   0.964749  0.125002       0.923729

    val_recall
0     0.913420
1     0.796537
2     0.935065
3     0.900000
4     0.935345
5     0.891775
6     0.926407
```

```
7     0.965368
8     0.861472
9     0.956710
10    0.892241
11    0.926407
12    0.965517
13    0.956140
14    0.908696
15    0.948052
16    0.935345
17    0.935065
18    0.969828
19    0.939655
```

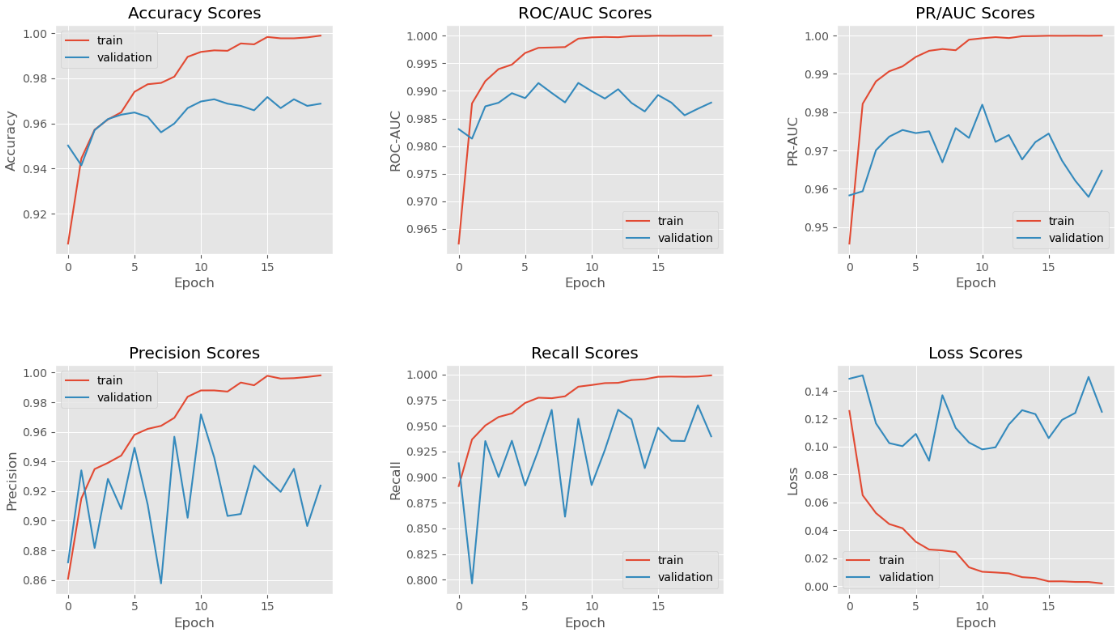
[ ]:

```
model = tf.keras.models.load_model('../modeling/logs/log_densenet/model.40-0.42.
  ↪hdf5')
```

```
2023-08-31 12:38:06.442945: I metal_plugin/src/device/metal_device.cc:1154]
Metal device set to: Apple M1 Pro
2023-08-31 12:38:06.442978: I metal_plugin/src/device/metal_device.cc:296]
systemMemory: 16.00 GB
2023-08-31 12:38:06.442991: I metal_plugin/src/device/metal_device.cc:313]
maxCacheSize: 5.33 GB
2023-08-31 12:38:06.443356: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:303]
Could not identify NUMA node of platform GPU ID 0, defaulting to 0. Your kernel
may not have been built with NUMA support.
2023-08-31 12:38:06.443659: I
tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:269]
Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 0
MB memory) -> physical PluggableDevice (device: 0, name: METAL, pci bus id:
<undefined>)
```

[ ]:

```
# evaluate model by displaying metrics with visualization
plt.style.use('ggplot')
sixplot2(history, 'auc', 'val_auc', 'auc_1', 'val_auc_1', 'precision',␣
  ↪'val_precision', 'recall', 'val_recall')
```



[ ]:

```
score = model.evaluate_generator(generator=valid_generator,
                                  steps=STEP_SIZE_VALID)

print("Validation Loss: " + str(score[0]))
print("Validation Accuracy: " + str(score[1]))
print("Validation Precision: " + str(score[2]))
print("Validation Recall: " + str(score[3]))
print("Validation ROC-AUC: " + str(score[4]))
print("Validation PR-AUC: " + str(score[5]))
```

```
Validation Loss: 0.1250956505537033
Validation Accuracy: 0.96875
Validation Precision: 0.9877833724021912
Validation Recall: 0.9642906785011292
Validation ROC-AUC: 0.9230769276618958
Validation PR-AUC: 0.939130425453186
```

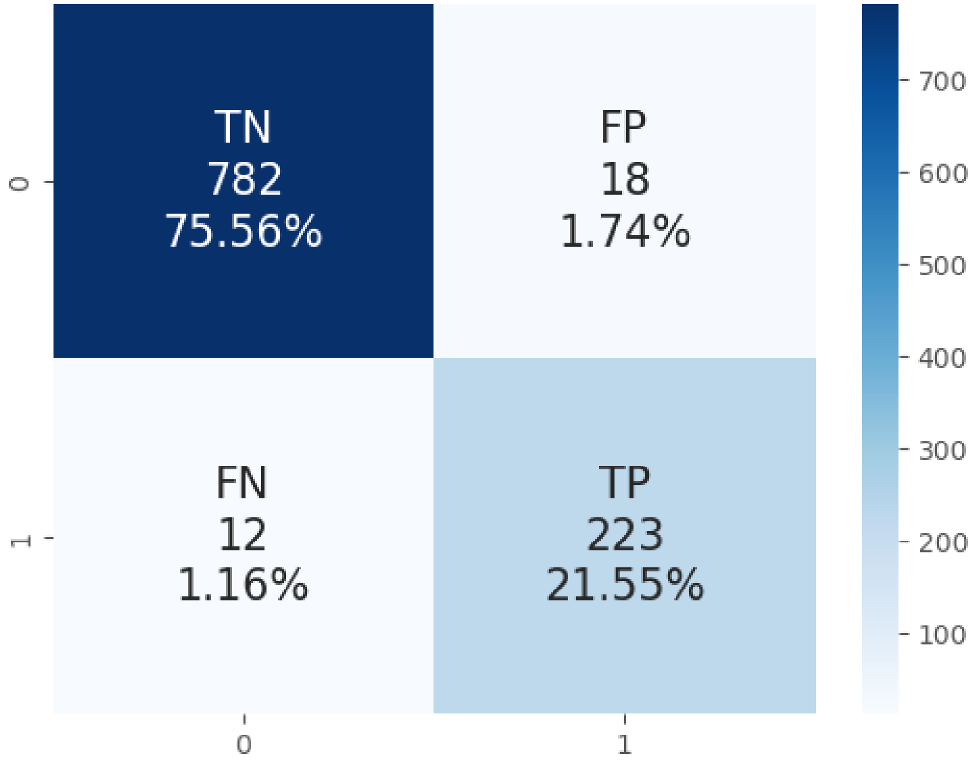
# 1 Testing

[ ]:

```
STEP_SIZE_TEST = test_generator.n // test_generator.batch_size

# get testing accuracy and loss
test_generator.reset()
# display confusion matrix visualization
pred = model.predict_generator(test_generator,
                               steps = STEP_SIZE_TEST,
                                                verbose = 1)
y_true = test_generator.classes
y_pred = pred > 0.5
make_confusion_matrix(y_true, y_pred)
```

```
1035/1035 [==============================] - 60s 58ms/step
```



[ ]:
```
predicted_class_indices = np.argmax(pred, axis=1)

labels = (train_generator.class_indices)
labels = dict((v,k) for k,v in labels.items())
predictions = [labels[k] for k in predicted_class_indices]
```

[ ]:
```
y_true
```

[ ]:
```
array([0, 0, 0, …, 1, 1, 1], dtype=int32)
```

[ ]:
```
labels
```

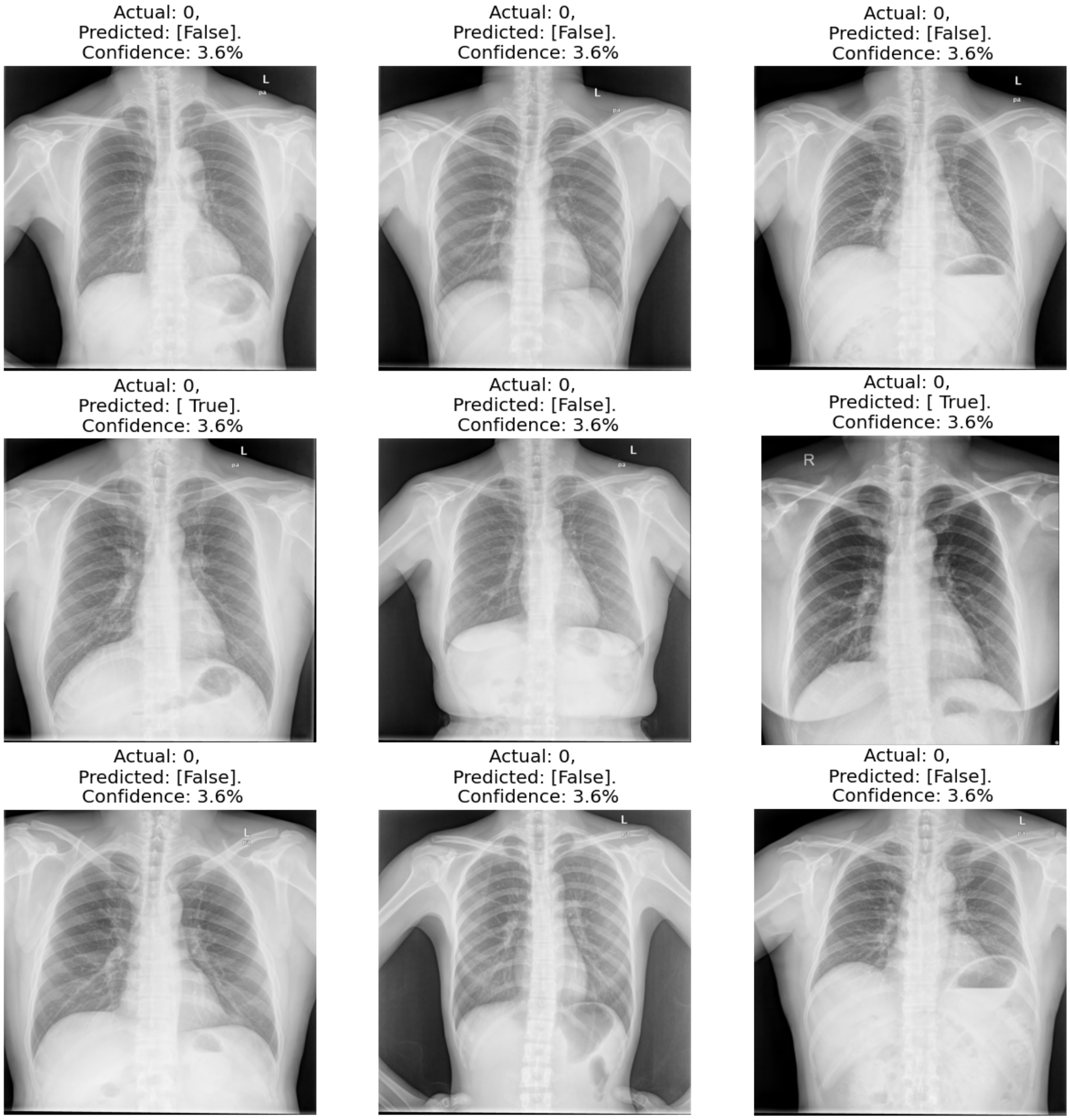
[ ]:
```
{0: 'Non-TB', 1: 'TB'}
```

[ ]:

```
plt.figure(figsize=(15,15))
for i in range(9):
    ax = plt.subplot(3,3,i+1)
    image = plt.imread(os.path.join('../data/augmented_sorted/test',␣
 ↪test_generator.filenames[i]))
    plt.imshow(image)

    predicted_class = y_pred[i]
    confidence = round(100 * (np.max(pred[0])),2)
    actual_class = y_true[i]

    plt.title(f"Actual: {actual_class}, \n Predicted: {predicted_class}. \n␣
 ↪Confidence: {confidence}%")
    plt.axis('off')
```



[ ]:

```
test_generator.filenames
```

[ ]:

```
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 …]
```
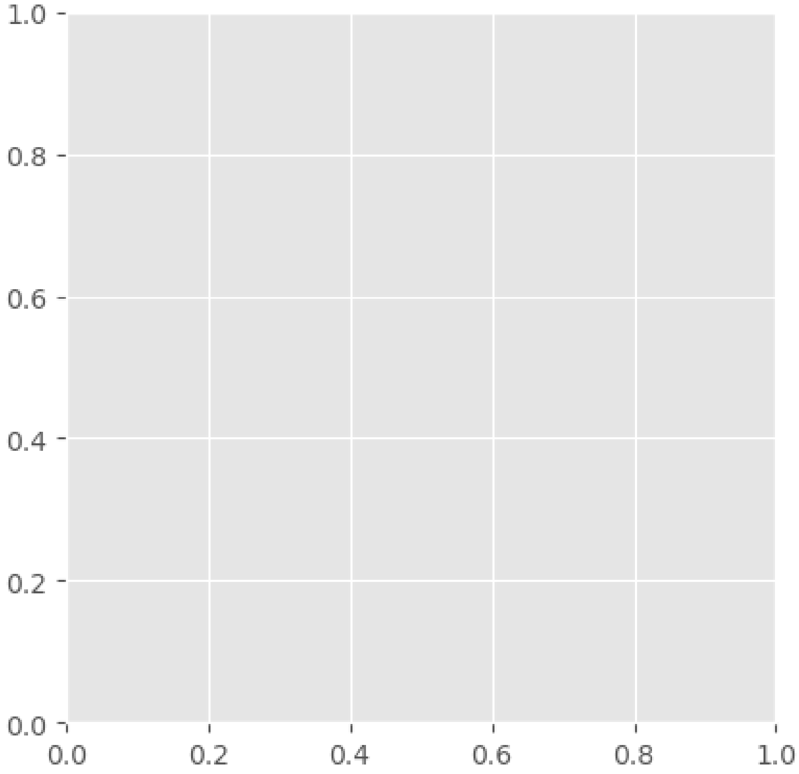

[ ]:

```
import glob
import cv2

# display sample of melanoma images
plt.style.use('ggplot')
paths = glob('../jpegs/split/train/1_mel/*.jpg')
fig, axes = plt.subplots(nrows=3, ncols=5, figsize=(16,6))
plt.suptitle('Melanoma Images', fontsize=16)
for i in range(0, 15):
    image = cv2.imread(paths[i], cv2.IMREAD_COLOR)
    image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
    image = cv2.resize(image, (256,256))
    x = i // 5
    y = i % 5
    axes[x, y].imshow(image, cmap=plt.cm.bone)
    axes[x, y].axis('off')
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/Volumes/Steven 4TB M2 SSD/Dropbox/Omdena/
 ↪Tuberculosis-Image-Classification-Project/modeling/DenseNet121 - TB.ipynb Cell␣
 ↪18 line 4
      <a href='vscode-notebook-cell:/Volumes/Steven%204TB%20M2%20SSD/Dropbox/
 ↪Omdena/Tuberculosis-Image-Classification-Project/modeling/DenseNet121%20-%20TB.
 ↪ipynb#X23sZmlsZQ%3D%3D?line=1'>2</a> for i in range(4):
      <a href='vscode-notebook-cell:/Volumes/Steven%204TB%20M2%20SSD/Dropbox/
 ↪Omdena/Tuberculosis-Image-Classification-Project/modeling/DenseNet121%20-%20TB.
 ↪ipynb#X23sZmlsZQ%3D%3D?line=2'>3</a>     image = x[i]
```

```
----> <a href='vscode-notebook-cell:/Volumes/Steven%204TB%20M2%20SSD/Dropbox/
↪Omdena/Tuberculosis-Image-Classification-Project/modeling/DenseNet121%20-%20TB.
↪ipynb#X23sZmlsZQ%3D%3D?line=3'>4</a>     plt.imshow(image.astype('uint8'))
      <a href='vscode-notebook-cell:/Volumes/Steven%204TB%20M2%20SSD/Dropbox/
↪Omdena/Tuberculosis-Image-Classification-Project/modeling/DenseNet121%20-%20TB.
↪ipynb#X23sZmlsZQ%3D%3D?line=4'>5</a>     plt.show()

File ~/miniconda3/envs/tf-exam-env/lib/python3.9/site-packages/matplotlib/pyplot.
↪py:3346, in imshow(X, cmap, norm, aspect, interpolation, alpha, vmin, vmax,␣
↪origin, extent, interpolation_stage, filternorm, filterrad, resample, url,␣
↪data, **kwargs)
   3325 @_copy_docstring_and_deprecators(Axes.imshow)
   3326 def imshow(
   3327     X: ArrayLike | PIL.Image.Image,
   (…)
   3344     **kwargs,
   3345 ) -> AxesImage:
-> 3346     __ret = gca().imshow(
   3347         X,
   3348         cmap=cmap,
   3349         norm=norm,
   3350         aspect=aspect,
   3351         interpolation=interpolation,
   3352         alpha=alpha,
   3353         vmin=vmin,
   3354         vmax=vmax,
   3355         origin=origin,
   3356         extent=extent,
   3357         interpolation_stage=interpolation_stage,
   3358         filternorm=filternorm,
   3359         filterrad=filterrad,
   3360         resample=resample,
   3361         url=url,
   3362         **({"data": data} if data is not None else {}),
   3363         **kwargs,
   3364     )
   3365     sci(__ret)
   3366     return __ret

File ~/miniconda3/envs/tf-exam-env/lib/python3.9/site-packages/matplotlib/
↪__init__.py:1465, in _preprocess_data.<locals>.inner(ax, data, *args, **kwargs)
   1462 @functools.wraps(func)
   1463 def inner(ax, *args, data=None, **kwargs):
   1464     if data is None:
-> 1465         return func(ax, *map(sanitize_sequence, args), **kwargs)
   1467     bound = new_sig.bind(ax, *args, **kwargs)
   1468     auto_label = (bound.arguments.get(label_namer)
   1469                   or bound.kwargs.get(label_namer))
```

```
File ~/miniconda3/envs/tf-exam-env/lib/python3.9/site-packages/matplotlib/axes/
 ↪_axes.py:5751, in Axes.imshow(self, X, cmap, norm, aspect, interpolation,␣
 ↪alpha, vmin, vmax, origin, extent, interpolation_stage, filternorm, filterrad ␣
 ↪resample, url, **kwargs)
   5748 if aspect is not None:
   5749     self.set_aspect(aspect)
-> 5751 im.set_data(X)
   5752 im.set_alpha(alpha)
   5753 if im.get_clip_path() is None:
   5754     # image does not already have clipping set, clip to axes patch

File ~/miniconda3/envs/tf-exam-env/lib/python3.9/site-packages/matplotlib/image
 ↪py:723, in _ImageBase.set_data(self, A)
    721 if isinstance(A, PIL.Image.Image):
    722     A = pil_to_array(A)  # Needed e.g. to apply png palette.
--> 723 self._A = self._normalize_image_array(A)
    724 self._imcache = None
    725 self.stale = True

File ~/miniconda3/envs/tf-exam-env/lib/python3.9/site-packages/matplotlib/image
 ↪py:693, in _ImageBase._normalize_image_array(A)
    691     A = A.squeeze(-1)  # If just (M, N, 1), assume scalar and apply␣
 ↪colormap.
    692 if not (A.ndim == 2 or A.ndim == 3 and A.shape[-1] in [3, 4]):
--> 693     raise TypeError(f"Invalid shape {A.shape} for image data")
    694 if A.ndim == 3:
    695     # If the input data has values outside the valid range (after
    696     # normalisation), we issue a warning and then clip X to the bounds
    697     # - otherwise casting wraps extreme values, hiding outliers and
    698     # making reliable interpretation impossible.
    699     high = 255 if np.issubdtype(A.dtype, np.integer) else 1

TypeError: Invalid shape (16, 224, 224, 3) for image data
```



```
[ ]: pred
```

```
[ ]: array([[3.6021210e-02],
            [6.3000777e-04],
            [8.3144296e-05],
            …,
            [9.9936748e-01],
            [1.0000000e+00],
            [9.9897009e-01]], dtype=float32)
```

```
[ ]:
```