notebook_vd

December 8, 2021

```python
[65]: import os
import sys
import json
import glob
import random
from random import shuffle
import time
import re
import math
import collections
from tqdm import tqdm
from config import EPOCH, EXPERIMENT
from logger import logger
import mlflow.tensorflow
from mlflow_utils import log_mlflow

import numpy as np
import pandas as pd
import cv2

import matplotlib.pyplot as plt

import dicom
import pydicom
from pydicom.pixel_data_handlers.util import apply_voi_lut

from sklearn import model_selection as sk_model_selection
from sklearn.metrics import roc_auc_score

import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers, Input
from tensorflow.keras import Input, Model
from tensorflow.keras.layers import Conv2D, GlobalAveragePooling2D, Dense
from tensorflow.keras.applications import *
from tensorflow.keras.optimizers import Adam, SGD, RMSprop
from tensorflow.keras.utils import to_categorical
```

```python
#from tensorflow.python.ops.numpy_ops import np_config
```

```python
[3]: run_params = {'epoch': EPOCH, 'experiment': EXPERIMENT}
     EPOCH = run_params.get('epoch', 40)
```

```python
[4]: UNZIP_DATA = False
     PROCESS_DATA = True
     LOAD_DATA = False
     data_dir = "./Data"
     mri_types = ["FLAIR", "T1w", "T2w", "T1wCE"]
     excluded_images = [109, 123, 709] # Bad images
```

```python
[5]: %%capture
     if (UNZIP_DATA):
         !unzip "Data/rsna-miccai-brain-tumor-radiogenomic-classification.zip" -d␣
     ↪"Data"
```

```python
[157]: if (PROCESS_DATA):
           train_df = pd.read_csv(os.path.join(data_dir, "train_labels.csv" ))
           train_df = train_df[~train_df.BraTS21ID.isin(excluded_images)]
           test_df = pd.read_csv(os.path.join(data_dir, "sample_submission.csv"))
       sample_submission = pd.read_csv(os.path.join(data_dir, "sample_submission.csv"))
```

```python
[158]: def load_image(path, size = 224):
           dicom_file = pydicom.read_file(path)
           dicom_pix = dicom_file.pixel_array
           if np.max(dicom_pix) != 0:
               dicom_pix = dicom_pix / np.max(data)
           dicom_pix = (dicom_pix * 255).astype(np.uint8)
           return cv2.resize(dicom_pix, (size, size))
```

```python
[159]: def get_all_image_paths(brats21id, img_type, folder='train'):
           if (img_type in mri_types):
               patient_path = os.path.join(data_dir, folder, str(brats21id).zfill(5))
               paths = sorted(glob.glob(os.path.join(patient_path, img_type,␣
       ↪"*")),key=lambda x: int(x[:-4].split("-")[-1]))
               return np.array(paths[0:len(paths):1])
           return None

       def get_all_images(brats21id, img_type, folder='train', size=225):
           return [load_image(path, size) for path in get_all_image_paths(brats21id,␣
       ↪img_type, folder)]
```

```python
[160]: def get_all_data_for_train(train_df, img_type, img_size=32):
           X = []
           y = []
```

```
        train_ids = []

        for i in tqdm(train_df.index):
            x = train_df.loc[i]
            images = get_all_images(int(x['BraTS21ID']), img_type, 'train',
    ↪img_size)
            label = x['MGMT_value']
            X += images
            y += [label] * len(images)
            train_ids += [int(x['BraTS21ID'])] * len(images)
            assert(len(X) == len(y))
        return np.array(X), np.array(y), np.array(train_ids)
```

[161]:
```
def get_all_data_for_test(test_df, img_type, img_size=32):
    X = []
    test_ids = []
    for i in tqdm(test_df.index):
        x = test_df.loc[i]
        images = get_all_images(int(x['BraTS21ID']), img_type, 'test', img_size)
        X += images
        test_ids += [int(x['BraTS21ID'])] * len(images)

    return np.array(X), np.array(test_ids)
```

[162]:
```
if (PROCESS_DATA):
    X, y, trainidt = get_all_data_for_train(train_df, 'T1wCE')
    X_test, testidt = get_all_data_for_test(test_df, 'T1wCE')
    X_train, X_valid, y_train, y_valid, trainidt_train, trainidt_valid =
    ↪sk_model_selection.train_test_split(X, y, trainidt, test_size=0.2,
    ↪random_state=42)
```

```
100%|                         | 582/582 [02:07<00:00,  4.56it/s]
100%|                         | 87/87 [00:38<00:00,  2.28it/s]
```

[163]:
```
if (PROCESS_DATA):
    np.save("x_train_data.npy", X_train)
    np.save("x_valid_data.npy", X_valid)
    np.save("y_train_data.npy", y_train)
    np.save("y_valid_data.npy",  y_valid)
elif (LOAD_DATA):
    X_train = np.load("x_train_data.npy")
    X_valid = np.load("x_valid_data.npy")
    y_train = np.load("y_train_data.npy")
    y_valid = np.load("y_valid_data.npy")
```

[164]:
```
#https://www.tensorflow.org/api_docs/python/tf/expand_dims
X_train = tf.expand_dims(X_train, axis=-1)
```

```
X_valid = tf.expand_dims(X_valid, axis=-1)
```

[165]:
```python
#https://www.tensorflow.org/api_docs/python/tf/keras/utils/to_categorical
y_train = to_categorical(y_train)
y_valid = to_categorical(y_valid)

print(f"X_train data: Rows={X_train.shape[0]}, Columns={X_train.shape[1]},
 →Type={type(X_train)}")
print(f"X_valid data: Rows={X_valid.shape[0]}, Columns={X_valid.shape[1]},
 →Type={type(X_valid)}")
print(f"y_train data: Rows={y_train.shape[0]}, Columns={y_train.shape[1]},
 →Type={type(y_train)}")
print(f"y_valid data: Rows={y_valid.shape[0]}, Columns={y_valid.shape[1]},
 →Type={type(y_valid)}")
```

```
X_train data: Rows=41019, Columns=32, Type=<class
'tensorflow.python.framework.ops.EagerTensor'>
X_valid data: Rows=10255, Columns=32, Type=<class
'tensorflow.python.framework.ops.EagerTensor'>
y_train data: Rows=41019, Columns=2, Type=<class 'numpy.ndarray'>
y_valid data: Rows=10255, Columns=2, Type=<class 'numpy.ndarray'>
```

0.1 Models

[166]:
```python
early_stopping_cb = tf.keras.callbacks.EarlyStopping(monitor="roc_auc",
 →mode='max', patience=3)
roc_auc = tf.keras.metrics.AUC(name='roc_auc', curve='ROC')
checkpoint_filepath = 'models/ls/best_models'
model_checkpoint_cb = tf.keras.callbacks.ModelCheckpoint(
    filepath=checkpoint_filepath,
    save_weights_only=False,
    monitor="auc",
    mode="max",
    save_best_only=True,
    save_freq="epoch",
    verbose=1,
)
```

[177]:
```python
def eval_model(model, model_name):
    y_pred = model.predict(X_valid)
    pred = np.argmax(y_pred, axis=1)
    res = pd.DataFrame(trainidt_valid)
    res[1] = pred
    res.columns = ["BraTS21ID", "MGMT_value"]
    result = res.groupby("BraTS21ID", as_index=False).mean()
    result = result.merge(train_df, on="BraTS21ID")
```

4

```
        auc = roc_auc_score(result.MGMT_value_y, result.MGMT_value_x,)
        print(f"Validation AUC={auc}")
        log_mlflow(run_params=run_params, model=model1, model_name=model_name,
    →y_true=valid, y_pred=pred)
```

[168]:
```python
def get_model1(name='model1'):
    np.random.seed(0)
    random.seed(42)
    tf.random.set_seed(42)

    inputs = keras.Input(shape=X_train.shape[1:])

    h = layers.experimental.preprocessing.Rescaling(1.0 / 255)(inputs)

    h = layers.Conv2D(64, kernel_size=(4, 4), activation="relu",
    →name="Conv_1")(h)
    h = layers.MaxPool2D(pool_size=(2, 2))(h)

    h = layers.Conv2D(32, kernel_size=(2, 2), activation="relu",
    →name="Conv_2")(h)
    h = layers.MaxPool2D(pool_size=(1, 1))(h)

    h = layers.Dropout(0.1)(h)

    h = layers.Flatten()(h)
    h = layers.Dense(32, activation="relu")(h)

    output = keras.layers.Dense(2, activation="softmax")(h)

    model = keras.Model(inputs, output, name=name)
    model.compile(loss="categorical_crossentropy",
    →optimizer=Adam(learning_rate=1e-3), metrics=[roc_auc])

    return model
```

[169]:
```python
keras.backend.clear_session()
model1 = get_model1()
model1.summary()
model1.fit(x=X_train, y = y_train, batch_size=64, epochs=40,
               callbacks=[model_checkpoint_cb, early_stopping_cb],
               validation_data=(X_valid, y_valid))
```

```
Model: "model1"

_____
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 32, 32, 1)]       0
```

```
-----------------------------------------------------------
rescaling (Rescaling)       (None, 32, 32, 1)        0
-----------------------------------------------------------
Conv_1 (Conv2D)             (None, 29, 29, 64)       1088
-----------------------------------------------------------
max_pooling2d (MaxPooling2D) (None, 14, 14, 64)      0
-----------------------------------------------------------
Conv_2 (Conv2D)             (None, 13, 13, 32)       8224
-----------------------------------------------------------
max_pooling2d_1 (MaxPooling2 (None, 13, 13, 32)      0
-----------------------------------------------------------
dropout (Dropout)           (None, 13, 13, 32)       0
-----------------------------------------------------------
flatten (Flatten)           (None, 5408)             0
-----------------------------------------------------------
dense (Dense)               (None, 32)               173088
-----------------------------------------------------------
dense_1 (Dense)             (None, 2)                66
===========================================================
Total params: 182,466
Trainable params: 182,466
Non-trainable params: 0

-----------------------------------------------------------
Epoch 1/40
641/641 [==============================] - 19s 29ms/step - loss: 0.6862 -
roc_auc: 0.5650 - val_loss: 0.6709 - val_roc_auc: 0.6094
[08/Dec/2021 07:17:30] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:17:30] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 2/40
641/641 [==============================] - 20s 31ms/step - loss: 0.6550 -
roc_auc: 0.6426 - val_loss: 0.6403 - val_roc_auc: 0.6619
[08/Dec/2021 07:17:50] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:17:50] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 3/40
641/641 [==============================] - 20s 31ms/step - loss: 0.5936 -
roc_auc: 0.7327 - val_loss: 0.5691 - val_roc_auc: 0.7559
[08/Dec/2021 07:18:10] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:18:10] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 4/40
641/641 [==============================] - 20s 31ms/step - loss: 0.5314 -
roc_auc: 0.7945 - val_loss: 0.5226 - val_roc_auc: 0.8000
[08/Dec/2021 07:18:30] WARNING - Can save best model only with auc available,
```

skipping.
[08/Dec/2021 07:18:30] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 5/40
641/641 [==============================] - 19s 30ms/step - loss: 0.4852 -
roc_auc: 0.8330 - val_loss: 0.4860 - val_roc_auc: 0.8301
[08/Dec/2021 07:18:49] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:18:49] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 6/40
641/641 [==============================] - 20s 31ms/step - loss: 0.4417 -
roc_auc: 0.8621 - val_loss: 0.4652 - val_roc_auc: 0.8463
[08/Dec/2021 07:19:09] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:19:09] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 7/40
641/641 [==============================] - 20s 31ms/step - loss: 0.4082 -
roc_auc: 0.8817 - val_loss: 0.4398 - val_roc_auc: 0.8630
[08/Dec/2021 07:19:29] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:19:29] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 8/40
641/641 [==============================] - 20s 32ms/step - loss: 0.3750 -
roc_auc: 0.8990 - val_loss: 0.4254 - val_roc_auc: 0.8722
[08/Dec/2021 07:19:50] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:19:50] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 9/40
641/641 [==============================] - 20s 31ms/step - loss: 0.3509 -
roc_auc: 0.9103 - val_loss: 0.4015 - val_roc_auc: 0.8881
[08/Dec/2021 07:20:10] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:20:10] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 10/40
641/641 [==============================] - 19s 29ms/step - loss: 0.3335 -
roc_auc: 0.9186 - val_loss: 0.3917 - val_roc_auc: 0.8943
[08/Dec/2021 07:20:28] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:20:28] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 11/40
641/641 [==============================] - 19s 30ms/step - loss: 0.3138 -
roc_auc: 0.9264 - val_loss: 0.3718 - val_roc_auc: 0.9031

[08/Dec/2021 07:20:47] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:20:47] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 12/40
641/641 [==============================] - 19s 30ms/step - loss: 0.2984 - roc_auc: 0.9328 - val_loss: 0.3760 - val_roc_auc: 0.9026
[08/Dec/2021 07:21:06] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:21:06] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 13/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2904 - roc_auc: 0.9359 - val_loss: 0.3692 - val_roc_auc: 0.9067
[08/Dec/2021 07:21:26] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:21:26] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 14/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2790 - roc_auc: 0.9401 - val_loss: 0.3742 - val_roc_auc: 0.9083
[08/Dec/2021 07:21:46] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:21:46] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 15/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2703 - roc_auc: 0.9428 - val_loss: 0.3565 - val_roc_auc: 0.9140
[08/Dec/2021 07:22:06] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:22:06] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 16/40
641/641 [==============================] - 19s 29ms/step - loss: 0.2647 - roc_auc: 0.9444 - val_loss: 0.3521 - val_roc_auc: 0.9162
[08/Dec/2021 07:22:24] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:22:24] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 17/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2589 - roc_auc: 0.9464 - val_loss: 0.3474 - val_roc_auc: 0.9169
[08/Dec/2021 07:22:44] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 07:22:44] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 18/40
641/641 [==============================] - 19s 30ms/step - loss: 0.2526 -

roc_auc: 0.9480 - val_loss: 0.3412 - val_roc_auc: 0.9205
[08/Dec/2021 07:23:04] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:23:04] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 19/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2474 -
roc_auc: 0.9496 - val_loss: 0.3562 - val_roc_auc: 0.9187
[08/Dec/2021 07:23:24] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:23:24] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 20/40
641/641 [==============================] - 21s 32ms/step - loss: 0.2433 -
roc_auc: 0.9509 - val_loss: 0.3489 - val_roc_auc: 0.9200
[08/Dec/2021 07:23:44] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:23:44] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 21/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2396 -
roc_auc: 0.9519 - val_loss: 0.3622 - val_roc_auc: 0.9179
[08/Dec/2021 07:24:04] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:24:04] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 22/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2379 -
roc_auc: 0.9522 - val_loss: 0.3501 - val_roc_auc: 0.9223
[08/Dec/2021 07:24:25] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:24:25] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 23/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2340 -
roc_auc: 0.9536 - val_loss: 0.3581 - val_roc_auc: 0.9209
[08/Dec/2021 07:24:44] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:24:44] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 24/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2328 -
roc_auc: 0.9534 - val_loss: 0.3636 - val_roc_auc: 0.9197
[08/Dec/2021 07:25:05] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:25:05] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 25/40

```
641/641 [==============================] - 20s 32ms/step - loss: 0.2318 -
roc_auc: 0.9536 - val_loss: 0.3574 - val_roc_auc: 0.9221
[08/Dec/2021 07:25:25] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:25:25] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 26/40
641/641 [==============================] - 21s 32ms/step - loss: 0.2286 -
roc_auc: 0.9545 - val_loss: 0.3437 - val_roc_auc: 0.9277
[08/Dec/2021 07:25:46] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:25:46] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 27/40
641/641 [==============================] - 19s 30ms/step - loss: 0.2292 -
roc_auc: 0.9548 - val_loss: 0.3635 - val_roc_auc: 0.9209
[08/Dec/2021 07:26:05] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:26:05] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 28/40
641/641 [==============================] - 20s 32ms/step - loss: 0.2242 -
roc_auc: 0.9561 - val_loss: 0.3571 - val_roc_auc: 0.9245
[08/Dec/2021 07:26:26] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:26:26] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 29/40
641/641 [==============================] - 22s 34ms/step - loss: 0.2256 -
roc_auc: 0.9562 - val_loss: 0.3711 - val_roc_auc: 0.9240
[08/Dec/2021 07:26:47] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:26:47] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 30/40
641/641 [==============================] - 21s 32ms/step - loss: 0.2222 -
roc_auc: 0.9564 - val_loss: 0.3635 - val_roc_auc: 0.9240
[08/Dec/2021 07:27:08] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:27:08] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 31/40
641/641 [==============================] - 20s 31ms/step - loss: 0.2201 -
roc_auc: 0.9571 - val_loss: 0.3579 - val_roc_auc: 0.9268
[08/Dec/2021 07:27:28] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:27:28] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
```
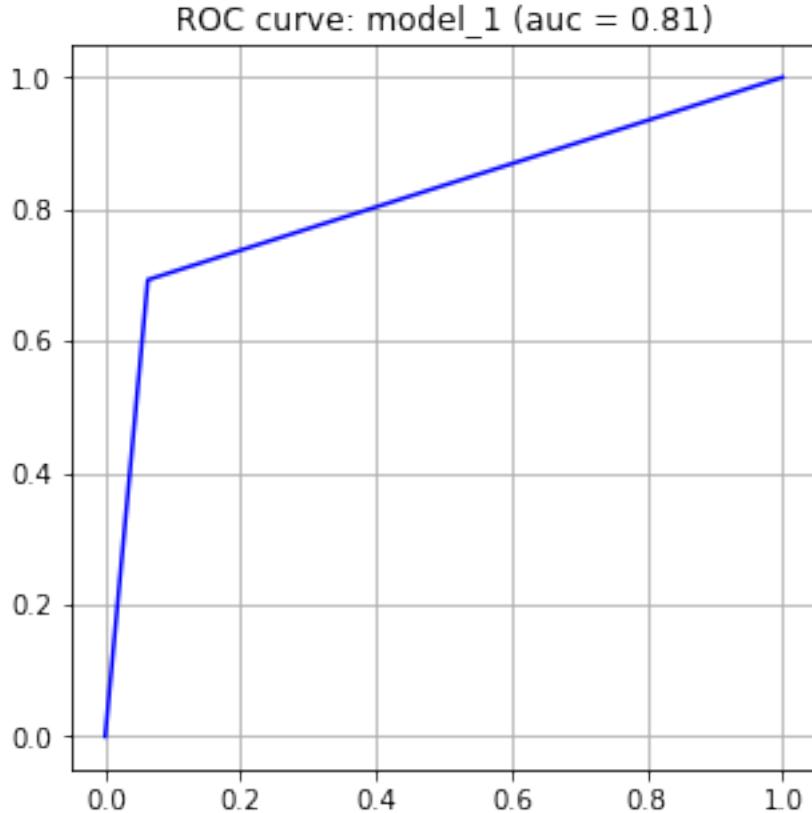
```
Epoch 32/40
641/641 [==============================] - 23s 36ms/step - loss: 0.2189 -
roc_auc: 0.9571 - val_loss: 0.3669 - val_roc_auc: 0.9247
[08/Dec/2021 07:27:51] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:27:51] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 33/40
641/641 [==============================] - 22s 35ms/step - loss: 0.2218 -
roc_auc: 0.9561 - val_loss: 0.3673 - val_roc_auc: 0.9242
[08/Dec/2021 07:28:14] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:28:14] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 34/40
641/641 [==============================] - 18s 29ms/step - loss: 0.2195 -
roc_auc: 0.9569 - val_loss: 0.3691 - val_roc_auc: 0.9235
[08/Dec/2021 07:28:32] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:28:32] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 35/40
641/641 [==============================] - 20s 30ms/step - loss: 0.2177 -
roc_auc: 0.9579 - val_loss: 0.3644 - val_roc_auc: 0.9266
[08/Dec/2021 07:28:51] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:28:51] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 36/40
641/641 [==============================] - 21s 33ms/step - loss: 0.2133 -
roc_auc: 0.9586 - val_loss: 0.3640 - val_roc_auc: 0.9275
[08/Dec/2021 07:29:13] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:29:13] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 37/40
641/641 [==============================] - 24s 37ms/step - loss: 0.2136 -
roc_auc: 0.9580 - val_loss: 0.3781 - val_roc_auc: 0.9239
[08/Dec/2021 07:29:36] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:29:36] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 38/40
641/641 [==============================] - 23s 36ms/step - loss: 0.2177 -
roc_auc: 0.9573 - val_loss: 0.3694 - val_roc_auc: 0.9275
[08/Dec/2021 07:29:59] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:29:59] WARNING - Early stopping conditioned on metric `auc`
```
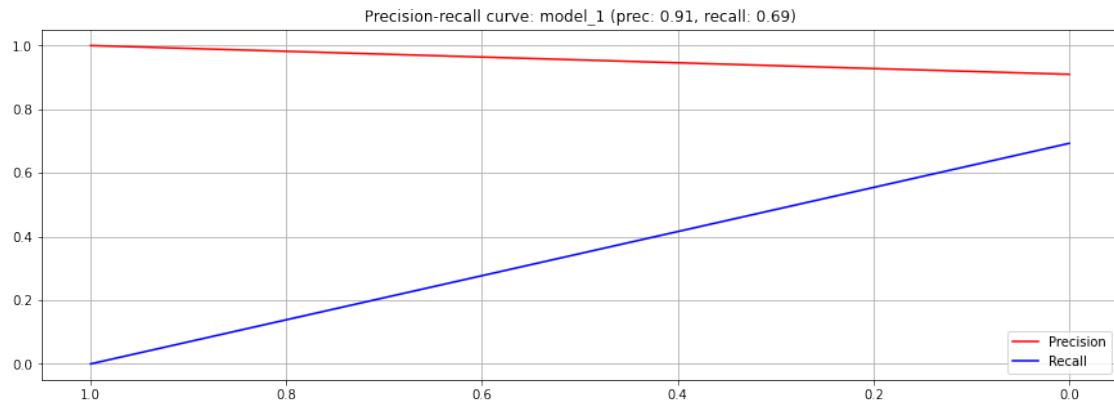
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 39/40
641/641 [==============================] - 19s 29ms/step - loss: 0.2158 -
roc_auc: 0.9578 - val_loss: 0.3779 - val_roc_auc: 0.9272
[08/Dec/2021 07:30:18] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:30:18] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc
Epoch 40/40
641/641 [==============================] - 24s 38ms/step - loss: 0.2119 -
roc_auc: 0.9589 - val_loss: 0.3773 - val_roc_auc: 0.9257
[08/Dec/2021 07:30:42] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:30:42] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are: loss,roc_auc,val_loss,val_roc_auc

[169]: <keras.callbacks.History at 0x1b17e44f0>

[179]: eval_model(model1, "model_1")

Validation AUC=0.9867982156492384
[08/Dec/2021 07:40:46] INFO - AUC: 0.815 | Recall: 0.693 | Precision: 0.910 |
F1: 0.787

ROC curve: model_1 (auc = 0.81)

Precision-recall curve: model_1 (prec: 0.91, recall: 0.69)

```
[184]: def get_model2(name='model2'):

           inputs_model = keras.Input(shape=X_train.shape[1:])

           input_dim = (32, 32, 1)
           input_tensor = Input(input_dim, name='input2d')
           efnet = DenseNet121(weights=None, include_top = False, input_shape=(32, 32,
       ↪3))
           mapping3feat = Conv2D(3, (3, 3), padding='same',
       ↪use_bias=False)(input_tensor)

           output = efnet(mapping3feat)
           output = GlobalAveragePooling2D()(output)
           output = Dense(2, activation='sigmoid')(output)

           model = Model(input_tensor, output)
           roc_auc = tf.keras.metrics.AUC(name='roc_auc', curve='ROC')

           model.compile(loss=tf.keras.losses.BinaryCrossentropy(from_logits=False),
               optimizer=Adam(learning_rate=1e-3),
               metrics=[roc_auc, tf.keras.metrics.BinaryAccuracy(name='bacc')],)


           return model
```

```
[185]: keras.backend.clear_session()
       model2 = get_model2()
       model2.summary()
       checkpoint_cb = keras.callbacks.ModelCheckpoint("model2.h5", monitor='val_auc',
        ↪mode='max', save_best_only=True)
```

```
model2.fit(x=X_train, y = y_train, batch_size=64, epochs=5,
            validation_data=(X_valid, y_valid),
            callbacks=[model_checkpoint_cb, early_stopping_cb])
```

Model: "model"

```
-------------------------------------------------------------------
Layer (type)                    Output Shape             Param #
===================================================================
input2d (InputLayer)            [(None, 32, 32, 1)]      0

-------------------------------------------------------------------
conv2d (Conv2D)                 (None, 32, 32, 3)        27

-------------------------------------------------------------------
densenet121 (Functional)        (None, 1, 1, 1024)       7037504

-------------------------------------------------------------------
global_average_pooling2d (Gl    (None, 1024)             0

-------------------------------------------------------------------
dense (Dense)                   (None, 2)                2050
===================================================================
Total params: 7,039,581
Trainable params: 6,955,933
Non-trainable params: 83,648

-------------------------------------------------------------------
Epoch 1/5
641/641 [==============================] - 247s 376ms/step - loss: 0.6992 -
roc_auc: 0.5473 - bacc: 0.5346 - val_loss: 1.0491 - val_roc_auc: 0.5618 -
val_bacc: 0.5584
[08/Dec/2021 07:45:59] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:45:59] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 2/5
641/641 [==============================] - 248s 387ms/step - loss: 0.6918 -
roc_auc: 0.5674 - bacc: 0.5445 - val_loss: 0.9736 - val_roc_auc: 0.5256 -
val_bacc: 0.5137
[08/Dec/2021 07:50:06] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:50:06] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 3/5
641/641 [==============================] - 239s 372ms/step - loss: 0.6721 -
roc_auc: 0.6147 - bacc: 0.5738 - val_loss: 0.6924 - val_roc_auc: 0.5915 -
val_bacc: 0.5546
[08/Dec/2021 07:54:05] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:54:05] WARNING - Early stopping conditioned on metric `auc`
```
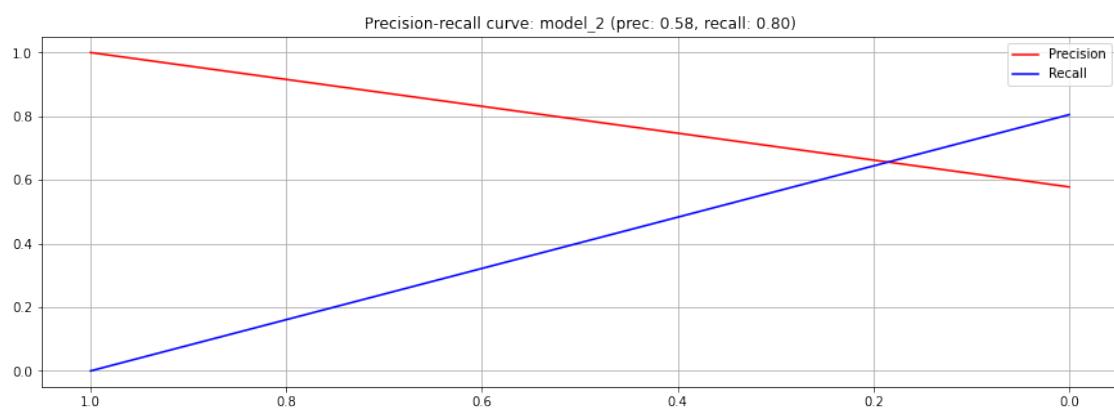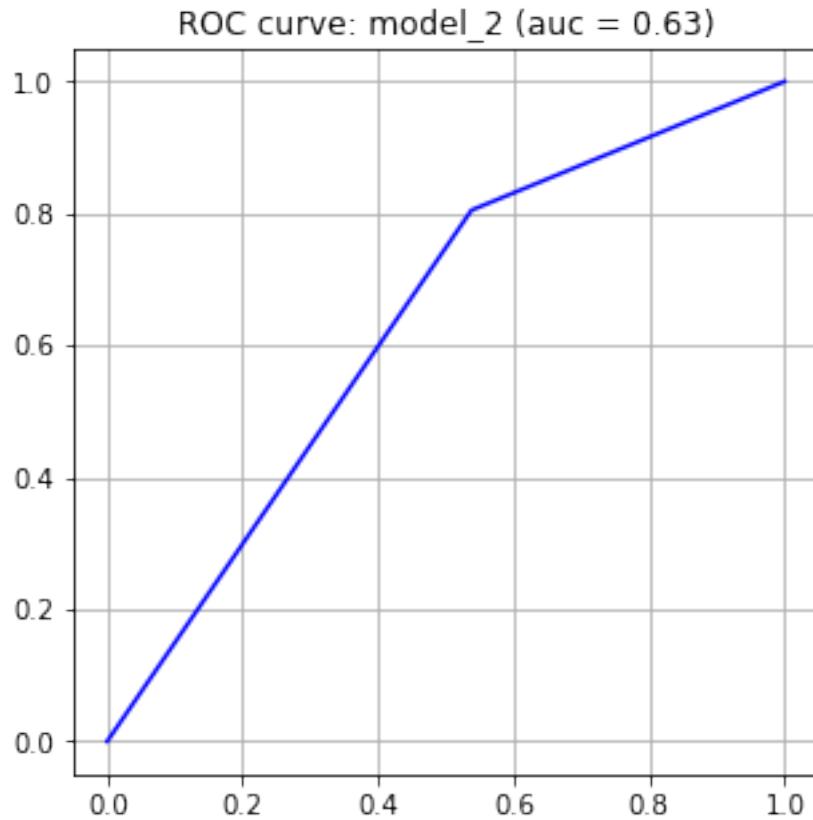
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 4/5
641/641 [==============================] - 237s 369ms/step - loss: 0.6557 -
roc_auc: 0.6491 - bacc: 0.5949 - val_loss: 0.6782 - val_roc_auc: 0.6261 -
val_bacc: 0.5796
[08/Dec/2021 07:58:02] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 07:58:02] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 5/5
641/641 [==============================] - 249s 388ms/step - loss: 0.6267 -
roc_auc: 0.6928 - bacc: 0.6231 - val_loss: 0.6987 - val_roc_auc: 0.6918 -
val_bacc: 0.6255
[08/Dec/2021 08:02:11] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 08:02:11] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc

[185]: <keras.callbacks.History at 0x1b1e427c0>

[188]: eval_model(model2, "model_2")

Validation AUC=0.8267089981111603
[08/Dec/2021 08:03:03] INFO - AUC: 0.634 | Recall: 0.805 | Precision: 0.578 |
F1: 0.673

ROC curve: model_2 (auc = 0.63)

Precision-recall curve: model_2 (prec: 0.58, recall: 0.80)

— Precision
— Recall

```python
[191]: from tensorflow import losses, optimizers
       from tensorflow.keras import Input, Model, models, layers

       def get_model3(name="model3"):

           inputs_model = keras.Input(shape=X_train.shape[1:])
```

```python
    input_dim = (32, 32, 1)
    input_tensor = Input(input_dim, name='input2d')

    # --- Define model
    conv = lambda x, filters,kernel_size, strides : layers.
↪Conv2D(filters=filters, kernel_size=kernel_size, strides=strides,␣
↪padding='same')(x)
    norm = lambda x : layers.BatchNormalization()(x)
    relu = lambda x : layers.ReLU()(x)
    pool = lambda x : layers.MaxPool2D(pool_size=(3, 3), strides=1,␣
↪padding='same')(x)
    conv2 = lambda filters, x : relu(norm(conv(x, filters,␣
↪kernel_size=(3,3),strides=(2, 2))))

    # --- Define 1x1, 3x3 and 5x5 convs
    conv1 = lambda filters, x : relu(norm(conv(x, filters, kernel_size=(1,␣
↪1),strides=1)))
    conv3 = lambda filters, x : relu(norm(conv(x, filters, kernel_size=(3,␣
↪3),strides=1)))
    conv5 = lambda filters, x : relu(norm(conv(x, filters, kernel_size=(5,␣
↪5),strides=1)))
    mpool = lambda x : relu(norm(pool(x)))

    # --- Define projection
    proj = lambda filters, x : layers.Conv2D(
        filters=filters,
        strides=1,
        kernel_size=(1, 1),
        padding='same')(x)

    tran = lambda x, filters, kernel_size, strides : layers.Conv2DTranspose(
        filters=filters, kernel_size=kernel_size, strides=strides,␣
↪padding='same')(x)

    tran_bloc = lambda filters, x : relu(norm(tran(x, filters,␣
↪kernel_size=(3,3), strides=(2, 2))))

    # --- Define concat function
    concat = lambda a, b : layers.Concatenate()([a, b])

    # --- Define inception function
    def inception(filters, prev_layer):
        b1 = proj(filters, prev_layer)
        p1 = conv1(filters, prev_layer)
        p2 = conv3(filters, b1)
        p3 = conv5(filters, b1)
```

```
            p4 = proj(filters, mpool(prev_layer))
            return layers.Concatenate()([p1,p2,p3,p4])


    # --- Define contracting layers
    l1 = conv1(32, input_tensor)
    l2 = inception(16, conv2(32, l1))
    l3 = inception(32, conv2(64, l2))
    l4 = inception(64, conv2(128, l3))

    # --- Define expanding layers
    l5 = tran_bloc(128, l4)
    l6 = tran_bloc(64, inception(64, conv3(128,concat(l3, l5))))
    l7 = tran_bloc(32, inception(32, conv3(64, concat(l2, l6))))
    l8 = inception(4, l7)

    # --- Create logits
    output = layers.Conv2D(filters=2, kernel_size=(3, 3),padding='same')(l8)
    output = GlobalAveragePooling2D()(output)
    output = Dense(2, activation='sigmoid')(output)

    # --- Create model
    model = Model(inputs=input_tensor, outputs=output)
    model.compile(optimizer=optimizers.Adam(learning_rate=1e-3),
        loss=tf.keras.losses.BinaryCrossentropy(from_logits=False),
        metrics=[roc_auc, tf.keras.metrics.BinaryAccuracy(name='bacc')],)

    model.summary()

    return model
```

```
[192]: keras.backend.clear_session()
       model3 = get_model3()
       model3.fit(x=X_train, y = y_train, batch_size=64, epochs=20,
               validation_data=(X_valid, y_valid),
               callbacks=[model_checkpoint_cb, early_stopping_cb])
```

```
Model: "model"
----------------------------------------------------------------------------
-------------------
Layer (type)                   Output Shape         Param #    Connected to
============================================================================
==================
input2d (InputLayer)           [(None, 32, 32, 1)]  0

----------------------------------------------------------------------------
-------------------
conv2d (Conv2D)                (None, 32, 32, 32)   64         input2d[0][0]
```

```
--------------------------------------------------------------------------------
------------------
batch_normalization (BatchNorma (None, 32, 32, 32)   128         conv2d[0][0]
--------------------------------------------------------------------------------
------------------
re_lu (ReLU)                    (None, 32, 32, 32)   0
batch_normalization[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_1 (Conv2D)               (None, 16, 16, 32)   9248        re_lu[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_1 (BatchNor (None, 16, 16, 32)   128         conv2d_1[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_1 (ReLU)                  (None, 16, 16, 32)   0
batch_normalization_1[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_2 (Conv2D)               (None, 16, 16, 16)   528         re_lu_1[0][0]
--------------------------------------------------------------------------------
------------------
max_pooling2d (MaxPooling2D)    (None, 16, 16, 32)   0           re_lu_1[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_3 (Conv2D)               (None, 16, 16, 16)   528         re_lu_1[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_4 (Conv2D)               (None, 16, 16, 16)   2320        conv2d_2[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_5 (Conv2D)               (None, 16, 16, 16)   6416        conv2d_2[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_5 (BatchNor (None, 16, 16, 32)   128
max_pooling2d[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_2 (BatchNor (None, 16, 16, 16)   64          conv2d_3[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_3 (BatchNor (None, 16, 16, 16)   64          conv2d_4[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_4 (BatchNor (None, 16, 16, 16)   64          conv2d_5[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_5 (ReLU)                  (None, 16, 16, 32)   0
```

```
                                              batch_normalization_5[0][0]
_____
re_lu_2 (ReLU)                (None, 16, 16, 16)   0
batch_normalization_2[0][0]
_____
re_lu_3 (ReLU)                (None, 16, 16, 16)   0
batch_normalization_3[0][0]
_____
re_lu_4 (ReLU)                (None, 16, 16, 16)   0
batch_normalization_4[0][0]
_____
conv2d_6 (Conv2D)             (None, 16, 16, 16)   528         re_lu_5[0][0]
_____
concatenate (Concatenate)     (None, 16, 16, 64)   0           re_lu_2[0][0]
                                                                re_lu_3[0][0]
                                                                re_lu_4[0][0]
                                                                conv2d_6[0][0]
_____
conv2d_7 (Conv2D)             (None, 8, 8, 64)     36928
concatenate[0][0]
_____
batch_normalization_6 (BatchNor (None, 8, 8, 64)   256         conv2d_7[0][0]
_____
re_lu_6 (ReLU)                (None, 8, 8, 64)     0
batch_normalization_6[0][0]
_____
conv2d_8 (Conv2D)             (None, 8, 8, 32)     2080        re_lu_6[0][0]
_____
max_pooling2d_1 (MaxPooling2D) (None, 8, 8, 64)    0           re_lu_6[0][0]
_____
conv2d_9 (Conv2D)             (None, 8, 8, 32)     2080        re_lu_6[0][0]
_____
conv2d_10 (Conv2D)            (None, 8, 8, 32)     9248        conv2d_8[0][0]
_____
conv2d_11 (Conv2D)            (None, 8, 8, 32)     25632       conv2d_8[0][0]
```

```
--------------------------------------------------------------------------------
------------------
batch_normalization_10 (BatchNo  (None, 8, 8, 64)    256
max_pooling2d_1[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_7 (BatchNor  (None, 8, 8, 32)    128          conv2d_9[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_8 (BatchNor  (None, 8, 8, 32)    128          conv2d_10[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_9 (BatchNor  (None, 8, 8, 32)    128          conv2d_11[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_10 (ReLU)                 (None, 8, 8, 64)     0
batch_normalization_10[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_7 (ReLU)                  (None, 8, 8, 32)     0
batch_normalization_7[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_8 (ReLU)                  (None, 8, 8, 32)     0
batch_normalization_8[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_9 (ReLU)                  (None, 8, 8, 32)     0
batch_normalization_9[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_12 (Conv2D)              (None, 8, 8, 32)     2080         re_lu_10[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_1 (Concatenate)     (None, 8, 8, 128)    0            re_lu_7[0][0]
                                                                  re_lu_8[0][0]
                                                                  re_lu_9[0][0]
                                                                  conv2d_12[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_13 (Conv2D)              (None, 4, 4, 128)    147584
concatenate_1[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_11 (BatchNo  (None, 4, 4, 128)   512          conv2d_13[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_11 (ReLU)                 (None, 4, 4, 128)    0
```

```
batch_normalization_11[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_14 (Conv2D)              (None, 4, 4, 64)    8256      re_lu_11[0][0]
----------------------------------------------------------------------------------
------------------
max_pooling2d_2 (MaxPooling2D)  (None, 4, 4, 128)   0         re_lu_11[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_15 (Conv2D)              (None, 4, 4, 64)    8256      re_lu_11[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_16 (Conv2D)              (None, 4, 4, 64)    36928     conv2d_14[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_17 (Conv2D)              (None, 4, 4, 64)    102464    conv2d_14[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_15 (BatchNo (None, 4, 4, 128)   512
max_pooling2d_2[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_12 (BatchNo (None, 4, 4, 64)    256       conv2d_15[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_13 (BatchNo (None, 4, 4, 64)    256       conv2d_16[0][0]
----------------------------------------------------------------------------------
------------------
batch_normalization_14 (BatchNo (None, 4, 4, 64)    256       conv2d_17[0][0]
----------------------------------------------------------------------------------
------------------
re_lu_15 (ReLU)                 (None, 4, 4, 128)   0
batch_normalization_15[0][0]
----------------------------------------------------------------------------------
------------------
re_lu_12 (ReLU)                 (None, 4, 4, 64)    0
batch_normalization_12[0][0]
----------------------------------------------------------------------------------
------------------
re_lu_13 (ReLU)                 (None, 4, 4, 64)    0
batch_normalization_13[0][0]
----------------------------------------------------------------------------------
------------------
re_lu_14 (ReLU)                 (None, 4, 4, 64)    0
batch_normalization_14[0][0]
----------------------------------------------------------------------------------
------------------
conv2d_18 (Conv2D)              (None, 4, 4, 64)    8256      re_lu_15[0][0]
```

```
--------------------------------------------------------------------------------
------------------
concatenate_2 (Concatenate)     (None, 4, 4, 256)    0          re_lu_12[0][0]
                                                                re_lu_13[0][0]
                                                                re_lu_14[0][0]
                                                                conv2d_18[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_transpose (Conv2DTranspo (None, 8, 8, 128)    295040
concatenate_2[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_16 (BatchNo (None, 8, 8, 128)    512
conv2d_transpose[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_16 (ReLU)                 (None, 8, 8, 128)    0
batch_normalization_16[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_3 (Concatenate)     (None, 8, 8, 256)    0
concatenate_1[0][0]
                                                                re_lu_16[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_19 (Conv2D)              (None, 8, 8, 128)    295040
concatenate_3[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_17 (BatchNo (None, 8, 8, 128)    512        conv2d_19[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_17 (ReLU)                 (None, 8, 8, 128)    0
batch_normalization_17[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_20 (Conv2D)              (None, 8, 8, 64)     8256       re_lu_17[0][0]
--------------------------------------------------------------------------------
------------------
max_pooling2d_3 (MaxPooling2D)  (None, 8, 8, 128)    0          re_lu_17[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_21 (Conv2D)              (None, 8, 8, 64)     8256       re_lu_17[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_22 (Conv2D)              (None, 8, 8, 64)     36928      conv2d_20[0][0]
--------------------------------------------------------------------------------
------------------
```

```
conv2d_23 (Conv2D)              (None, 8, 8, 64)     102464    conv2d_20[0][0]
_____
batch_normalization_21 (BatchNo (None, 8, 8, 128)    512
max_pooling2d_3[0][0]
_____
batch_normalization_18 (BatchNo (None, 8, 8, 64)     256       conv2d_21[0][0]
_____
batch_normalization_19 (BatchNo (None, 8, 8, 64)     256       conv2d_22[0][0]
_____
batch_normalization_20 (BatchNo (None, 8, 8, 64)     256       conv2d_23[0][0]
_____
re_lu_21 (ReLU)                 (None, 8, 8, 128)    0
batch_normalization_21[0][0]
_____
re_lu_18 (ReLU)                 (None, 8, 8, 64)     0
batch_normalization_18[0][0]
_____
re_lu_19 (ReLU)                 (None, 8, 8, 64)     0
batch_normalization_19[0][0]
_____
re_lu_20 (ReLU)                 (None, 8, 8, 64)     0
batch_normalization_20[0][0]
_____
conv2d_24 (Conv2D)              (None, 8, 8, 64)     8256      re_lu_21[0][0]
_____
concatenate_4 (Concatenate)     (None, 8, 8, 256)    0         re_lu_18[0][0]
                                                              re_lu_19[0][0]
                                                              re_lu_20[0][0]
                                                              conv2d_24[0][0]
_____
conv2d_transpose_1 (Conv2DTrans (None, 16, 16, 64)   147520
concatenate_4[0][0]
_____
batch_normalization_22 (BatchNo (None, 16, 16, 64)   256
conv2d_transpose_1[0][0]
_____
```

```
------------------
re_lu_22 (ReLU)                (None, 16, 16, 64)   0
batch_normalization_22[0][0]
_____
------------------
concatenate_5 (Concatenate)    (None, 16, 16, 128)  0
concatenate[0][0]

                                                                 re_lu_22[0][0]
_____
------------------
conv2d_25 (Conv2D)             (None, 16, 16, 64)   73792
concatenate_5[0][0]
_____
------------------
batch_normalization_23 (BatchNo (None, 16, 16, 64)  256          conv2d_25[0][0]
_____
------------------
re_lu_23 (ReLU)                (None, 16, 16, 64)   0
batch_normalization_23[0][0]
_____
------------------
conv2d_26 (Conv2D)             (None, 16, 16, 32)   2080         re_lu_23[0][0]
_____
------------------
max_pooling2d_4 (MaxPooling2D)  (None, 16, 16, 64)  0            re_lu_23[0][0]
_____
------------------
conv2d_27 (Conv2D)             (None, 16, 16, 32)   2080         re_lu_23[0][0]
_____
------------------
conv2d_28 (Conv2D)             (None, 16, 16, 32)   9248         conv2d_26[0][0]
_____
------------------
conv2d_29 (Conv2D)             (None, 16, 16, 32)   25632        conv2d_26[0][0]
_____
------------------
batch_normalization_27 (BatchNo (None, 16, 16, 64)  256
max_pooling2d_4[0][0]
_____
------------------
batch_normalization_24 (BatchNo (None, 16, 16, 32)  128          conv2d_27[0][0]
_____
------------------
batch_normalization_25 (BatchNo (None, 16, 16, 32)  128          conv2d_28[0][0]
_____
------------------
batch_normalization_26 (BatchNo (None, 16, 16, 32)  128          conv2d_29[0][0]
_____
```

```
------------------
re_lu_27 (ReLU)                  (None, 16, 16, 64)    0
batch_normalization_27[0][0]
-----------------------------------------------------------------------------
------------------
re_lu_24 (ReLU)                  (None, 16, 16, 32)    0
batch_normalization_24[0][0]
-----------------------------------------------------------------------------
------------------
re_lu_25 (ReLU)                  (None, 16, 16, 32)    0
batch_normalization_25[0][0]
-----------------------------------------------------------------------------
------------------
re_lu_26 (ReLU)                  (None, 16, 16, 32)    0
batch_normalization_26[0][0]
-----------------------------------------------------------------------------
------------------
conv2d_30 (Conv2D)               (None, 16, 16, 32)    2080      re_lu_27[0][0]
-----------------------------------------------------------------------------
------------------
concatenate_6 (Concatenate)      (None, 16, 16, 128)   0         re_lu_24[0][0]
                                                                 re_lu_25[0][0]
                                                                 re_lu_26[0][0]
                                                                 conv2d_30[0][0]
-----------------------------------------------------------------------------
------------------
conv2d_transpose_2 (Conv2DTrans  (None, 32, 32, 32)    36896
concatenate_6[0][0]
-----------------------------------------------------------------------------
------------------
batch_normalization_28 (BatchNo  (None, 32, 32, 32)    128
conv2d_transpose_2[0][0]
-----------------------------------------------------------------------------
------------------
re_lu_28 (ReLU)                  (None, 32, 32, 32)    0
batch_normalization_28[0][0]
-----------------------------------------------------------------------------
------------------
conv2d_31 (Conv2D)               (None, 32, 32, 4)     132       re_lu_28[0][0]
-----------------------------------------------------------------------------
------------------
max_pooling2d_5 (MaxPooling2D)   (None, 32, 32, 32)    0         re_lu_28[0][0]
-----------------------------------------------------------------------------
------------------
conv2d_32 (Conv2D)               (None, 32, 32, 4)     132       re_lu_28[0][0]
-----------------------------------------------------------------------------
------------------
conv2d_33 (Conv2D)               (None, 32, 32, 4)     148       conv2d_31[0][0]
```

```
--------------------------------------------------------------------------------
------------------
conv2d_34 (Conv2D)              (None, 32, 32, 4)    404         conv2d_31[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_32 (BatchNo (None, 32, 32, 32)   128
max_pooling2d_5[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_29 (BatchNo (None, 32, 32, 4)    16          conv2d_32[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_30 (BatchNo (None, 32, 32, 4)    16          conv2d_33[0][0]
--------------------------------------------------------------------------------
------------------
batch_normalization_31 (BatchNo (None, 32, 32, 4)    16          conv2d_34[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_32 (ReLU)                 (None, 32, 32, 32)   0
batch_normalization_32[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_29 (ReLU)                 (None, 32, 32, 4)    0
batch_normalization_29[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_30 (ReLU)                 (None, 32, 32, 4)    0
batch_normalization_30[0][0]
--------------------------------------------------------------------------------
------------------
re_lu_31 (ReLU)                 (None, 32, 32, 4)    0
batch_normalization_31[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_35 (Conv2D)              (None, 32, 32, 4)    132         re_lu_32[0][0]
--------------------------------------------------------------------------------
------------------
concatenate_7 (Concatenate)     (None, 32, 32, 16)   0           re_lu_29[0][0]
                                                                 re_lu_30[0][0]
                                                                 re_lu_31[0][0]
                                                                 conv2d_35[0][0]
--------------------------------------------------------------------------------
------------------
conv2d_36 (Conv2D)              (None, 32, 32, 2)    290
concatenate_7[0][0]
--------------------------------------------------------------------------------
------------------
global_average_pooling2d (Globa (None, 2)            0           conv2d_36[0][0]
```

```
--------------------------------------------------------------------------------
-------------------
dense (Dense)                     (None, 2)              6
global_average_pooling2d[0][0]
================================================================================
==================
Total params: 1,471,260
Trainable params: 1,467,748
Non-trainable params: 3,512
--------------------------------------------------------------------------------
-------------------
Epoch 1/20
641/641 [==============================] - 314s 486ms/step - loss: 0.6851 -
roc_auc: 0.6646 - bacc: 0.5391 - val_loss: 0.6955 - val_roc_auc: 0.5413 -
val_bacc: 0.5246
[08/Dec/2021 08:09:12] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 08:09:12] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 2/20
641/641 [==============================] - 403s 629ms/step - loss: 0.6383 -
roc_auc: 0.6670 - bacc: 0.6044 - val_loss: 0.6384 - val_roc_auc: 0.6875 -
val_bacc: 0.6184
[08/Dec/2021 08:15:55] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 08:15:55] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 3/20
641/641 [==============================] - 367s 572ms/step - loss: 0.5503 -
roc_auc: 0.7695 - bacc: 0.6745 - val_loss: 0.5315 - val_roc_auc: 0.7938 -
val_bacc: 0.6927
[08/Dec/2021 08:22:02] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 08:22:02] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 4/20
641/641 [==============================] - 361s 563ms/step - loss: 0.4648 -
roc_auc: 0.8407 - bacc: 0.7304 - val_loss: 0.4704 - val_roc_auc: 0.8439 -
val_bacc: 0.7332
[08/Dec/2021 08:28:03] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 08:28:03] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 5/20
```

641/641 [==============================] - 368s 575ms/step - loss: 0.3993 - roc_auc: 0.8819 - bacc: 0.7659 - val_loss: 0.4356 - val_roc_auc: 0.8647 - val_bacc: 0.7517
[08/Dec/2021 08:34:11] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 08:34:11] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 6/20
641/641 [==============================] - 382s 596ms/step - loss: 0.3566 - roc_auc: 0.9046 - bacc: 0.7906 - val_loss: 0.3923 - val_roc_auc: 0.8860 - val_bacc: 0.7711
[08/Dec/2021 08:40:33] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 08:40:33] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 7/20
641/641 [==============================] - 359s 559ms/step - loss: 0.3229 - roc_auc: 0.9201 - bacc: 0.8071 - val_loss: 0.3760 - val_roc_auc: 0.8978 - val_bacc: 0.7827
[08/Dec/2021 08:46:32] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 08:46:32] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 8/20
641/641 [==============================] - 316s 494ms/step - loss: 0.3014 - roc_auc: 0.9297 - bacc: 0.8192 - val_loss: 0.3915 - val_roc_auc: 0.8887 - val_bacc: 0.7731
[08/Dec/2021 08:51:48] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 08:51:48] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 9/20
641/641 [==============================] - 262s 408ms/step - loss: 0.2837 - roc_auc: 0.9363 - bacc: 0.8262 - val_loss: 0.3640 - val_roc_auc: 0.9078 - val_bacc: 0.7939
[08/Dec/2021 08:56:10] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 08:56:10] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are: loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 10/20
641/641 [==============================] - 288s 450ms/step - loss: 0.2740 - roc_auc: 0.9403 - bacc: 0.8325 - val_loss: 0.4649 - val_roc_auc: 0.8869 - val_bacc: 0.7756
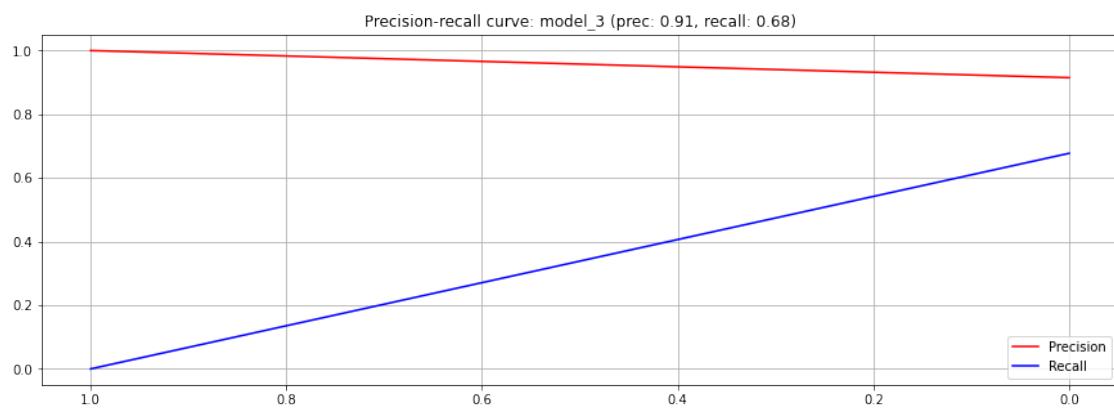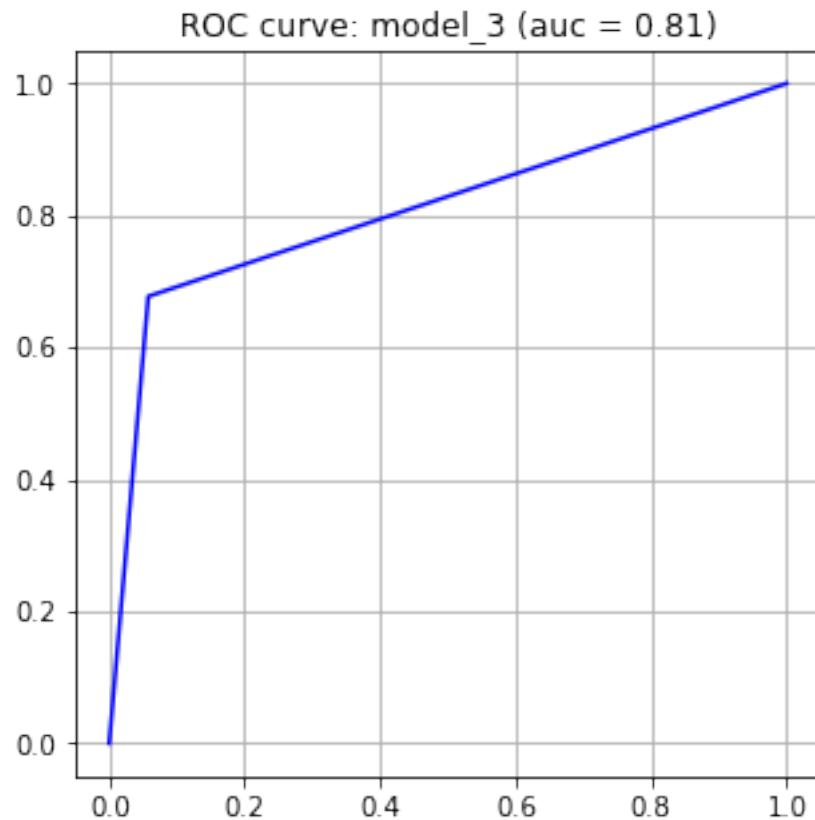
[08/Dec/2021 09:00:58] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:00:58] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 11/20
641/641 [==============================] - 323s 503ms/step - loss: 0.2630 - roc_auc: 0.9438 - bacc: 0.8359 - val_loss: 0.3501 - val_roc_auc: 0.9152 - val_bacc: 0.8027
[08/Dec/2021 09:06:21] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:06:21] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 12/20
641/641 [==============================] - 291s 453ms/step - loss: 0.2537 - roc_auc: 0.9466 - bacc: 0.8393 - val_loss: 0.3800 - val_roc_auc: 0.9101 - val_bacc: 0.7975
[08/Dec/2021 09:11:12] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:11:12] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 13/20
641/641 [==============================] - 297s 463ms/step - loss: 0.2465 - roc_auc: 0.9490 - bacc: 0.8442 - val_loss: 0.3771 - val_roc_auc: 0.9105 - val_bacc: 0.7983
[08/Dec/2021 09:16:08] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:16:08] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 14/20
641/641 [==============================] - 298s 464ms/step - loss: 0.2420 - roc_auc: 0.9505 - bacc: 0.8464 - val_loss: 0.3818 - val_roc_auc: 0.9163 - val_bacc: 0.8064
[08/Dec/2021 09:21:06] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:21:06] WARNING - Early stopping conditioned on metric `auc` which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 15/20
641/641 [==============================] - 283s 442ms/step - loss: 0.2380 - roc_auc: 0.9516 - bacc: 0.8480 - val_loss: 0.3562 - val_roc_auc: 0.9175 - val_bacc: 0.8062
[08/Dec/2021 09:25:49] WARNING - Can save best model only with auc available, skipping.
[08/Dec/2021 09:25:49] WARNING - Early stopping conditioned on metric `auc`

which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 16/20
641/641 [==============================] - 299s 467ms/step - loss: 0.2339 -
roc_auc: 0.9530 - bacc: 0.8492 - val_loss: 0.3501 - val_roc_auc: 0.9219 -
val_bacc: 0.8109
[08/Dec/2021 09:30:48] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 09:30:48] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 17/20
641/641 [==============================] - 271s 422ms/step - loss: 0.2303 -
roc_auc: 0.9539 - bacc: 0.8515 - val_loss: 0.3419 - val_roc_auc: 0.9233 -
val_bacc: 0.8134
[08/Dec/2021 09:35:19] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 09:35:19] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 18/20
641/641 [==============================] - 258s 402ms/step - loss: 0.2291 -
roc_auc: 0.9546 - bacc: 0.8529 - val_loss: 0.3642 - val_roc_auc: 0.9224 -
val_bacc: 0.8130
[08/Dec/2021 09:39:37] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 09:39:37] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 19/20
641/641 [==============================] - 334s 521ms/step - loss: 0.2252 -
roc_auc: 0.9554 - bacc: 0.8536 - val_loss: 0.3472 - val_roc_auc: 0.9269 -
val_bacc: 0.8196
[08/Dec/2021 09:45:10] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 09:45:10] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc
Epoch 20/20
641/641 [==============================] - 302s 470ms/step - loss: 0.2255 -
roc_auc: 0.9553 - bacc: 0.8532 - val_loss: 0.3705 - val_roc_auc: 0.9234 -
val_bacc: 0.8157
[08/Dec/2021 09:50:12] WARNING - Can save best model only with auc available,
skipping.
[08/Dec/2021 09:50:12] WARNING - Early stopping conditioned on metric `auc`
which is not available. Available metrics are:
loss,roc_auc,bacc,val_loss,val_roc_auc,val_bacc

[192]: <keras.callbacks.History at 0x1b1e42a00>

[193]: eval_model(model3, "model_3")

Validation AUC=0.9909375879114254
[08/Dec/2021 09:50:28] INFO - AUC: 0.810 | Recall: 0.677 | Precision: 0.915 |
F1: 0.778

ROC curve: model_3 (auc = 0.81)

Precision-recall curve: model_3 (prec: 0.91, recall: 0.68)

0.2 Submission

```
[194]: SUBMIT = False
```

```
[195]: if (SUBMIT):
           res.columns=['BraTS21ID','MGMT_value']
           result = res.groupby('BraTS21ID',as_index=False).mean()
           result['BraTS21ID'] = sample_submission['BraTS21ID']
           result['MGMT_value'] = result['MGMT_value'].apply(lambda x:round(x*10)/10)
           result.to_csv('submission_vincent_dandenault.csv',index=False)
```