ResNet50V2

April 22, 2020

[1]:
```
import os

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

from tensorflow.python.client import device_lib
print(device_lib.list_local_devices())

os.environ['OMP_NUM_THREADS'] = '1'
os.environ['CUDA_VISIBLE_DEVICES'] = '-1'
tf.__version__
```

```
[name: "/device:CPU:0"
device_type: "CPU"
memory_limit: 268435456
locality {
}
incarnation: 6397460011154959715
, name: "/device:GPU:0"
device_type: "GPU"
memory_limit: 4930941747
locality {
  bus_id: 1
  links {
  }
}
incarnation: 17712447421792666280
physical_device_desc: "device: 0, name: GeForce GTX 1060, pci bus id:
0000:01:00.0, compute capability: 6.1"
]
```

[1]:
```
'2.1.0'
```

[2]:
```
DATA_LIST = os.listdir('all/train')
DATASET_PATH  = 'all/train'
TEST_DIR =  'all/test'
```

```
IMAGE_SIZE    = (224, 224)
NUM_CLASSES   = len(DATA_LIST)
BATCH_SIZE    = 10  # try reducing batch size or freeze more layers if your GPU␣
 ↪runs out of memory
NUM_EPOCHS    = 100
LEARNING_RATE = 0.0001 # start off with high rate first 0.001 and experiment␣
 ↪with reducing it gradually
```

[3]:
```
train_datagen = ImageDataGenerator(rescale=1./
 ↪255,rotation_range=50,featurewise_center = True,
                                    featurewise_std_normalization =␣
 ↪True,width_shift_range=0.2,
                                    height_shift_range=0.2,shear_range=0.
 ↪25,zoom_range=0.1,
                                    zca_whitening = True,channel_shift_range = 20,
                                    horizontal_flip = True,vertical_flip = True,
                                    validation_split = 0.2,fill_mode='constant')


train_batches = train_datagen.
 ↪flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                      ␣
 ↪shuffle=True,batch_size=BATCH_SIZE,
                                                       subset = "training",seed=42,
                                                       class_mode="categorical")

valid_batches = train_datagen.
 ↪flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                      ␣
 ↪shuffle=True,batch_size=BATCH_SIZE,
                                                       subset = "validation",
                                                      ␣
 ↪seed=42,class_mode="categorical")
```

```
Found 216 images belonging to 4 classes.
Found 54 images belonging to 4 classes.
```

```
C:\Users\tanzi\Anaconda3\lib\site-
packages\keras_preprocessing\image\image_data_generator.py:341: UserWarning:
This ImageDataGenerator specifies `zca_whitening` which overrides setting
of`featurewise_std_normalization`.
  warnings.warn('This ImageDataGenerator specifies '
```

[4]:
```
# raise NotImplementedError("Build your model based on an architecture of your␣
 ↪choice "
#                           "A sample model summary is shown below")
```

```
# Implement VGG16
from tensorflow.keras.layers import Flatten, Dense, Dropout
from tensorflow.keras.models import Sequential

resNet50V2 = tf.keras.applications.resnet_v2.ResNet50V2(include_top=False,␣
 ↪weights='imagenet', input_shape=(224, 224, 3), pooling='None', classes=4)
resNet50V2.trainable = False

print(resNet50V2.summary())

covid_model = Sequential()
covid_model.add(resNet50V2)
covid_model.add(tf.keras.layers.AveragePooling2D(pool_size=7))
covid_model.add(Flatten())
covid_model.add(Dropout(0.3))
covid_model.add(Dense(256, activation='relu'))
covid_model.add(Dropout(0.2))
covid_model.add(Dense(4, activation='softmax', kernel_initializer='he_normal'))

covid_model.build(input_shape=(224, 224, 3))
covid_model.summary()
```

```
Model: "resnet50v2"
__________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================
==================
input_1 (InputLayer)            [(None, 224, 224, 3) 0
__________________________________________________________________________________
__________________
conv1_pad (ZeroPadding2D)       (None, 230, 230, 3)  0           input_1[0][0]
__________________________________________________________________________________
__________________
conv1_conv (Conv2D)             (None, 112, 112, 64) 9472        conv1_pad[0][0]
__________________________________________________________________________________
__________________
pool1_pad (ZeroPadding2D)       (None, 114, 114, 64) 0
conv1_conv[0][0]
__________________________________________________________________________________
__________________
pool1_pool (MaxPooling2D)       (None, 56, 56, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________
__________________
conv2_block1_preact_bn (BatchNo (None, 56, 56, 64)   256
pool1_pool[0][0]
__________________________________________________________________________________
```

```
------------------
conv2_block1_preact_relu (Activ (None, 56, 56, 64)   0
conv2_block1_preact_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_1_conv (Conv2D)    (None, 56, 56, 64)   4096
conv2_block1_preact_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_1_bn (BatchNormali (None, 56, 56, 64)   256
conv2_block1_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_1_relu (Activation (None, 56, 56, 64)   0
conv2_block1_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_2_pad (ZeroPadding (None, 58, 58, 64)   0
conv2_block1_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_2_conv (Conv2D)    (None, 56, 56, 64)   36864
conv2_block1_2_pad[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_2_bn (BatchNormali (None, 56, 56, 64)   256
conv2_block1_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_2_relu (Activation (None, 56, 56, 64)   0
conv2_block1_2_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_0_conv (Conv2D)    (None, 56, 56, 256)  16640
conv2_block1_preact_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_3_conv (Conv2D)    (None, 56, 56, 256)  16640
conv2_block1_2_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block1_out (Add)          (None, 56, 56, 256)  0
conv2_block1_0_conv[0][0]
conv2_block1_3_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv2_block2_preact_bn (BatchNo (None, 56, 56, 256)  1024
conv2_block1_out[0][0]
```

```
----------------------------------------------------------------------------------------------------
conv2_block2_preact_relu (Activ (None, 56, 56, 256)  0
conv2_block2_preact_bn[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_1_conv (Conv2D)    (None, 56, 56, 64)   16384
conv2_block2_preact_relu[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_1_bn (BatchNormali (None, 56, 56, 64)   256
conv2_block2_1_conv[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_1_relu (Activation (None, 56, 56, 64)   0
conv2_block2_1_bn[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_2_pad (ZeroPadding (None, 58, 58, 64)   0
conv2_block2_1_relu[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_2_conv (Conv2D)    (None, 56, 56, 64)   36864
conv2_block2_2_pad[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_2_bn (BatchNormali (None, 56, 56, 64)   256
conv2_block2_2_conv[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_2_relu (Activation (None, 56, 56, 64)   0
conv2_block2_2_bn[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_3_conv (Conv2D)    (None, 56, 56, 256)  16640
conv2_block2_2_relu[0][0]
----------------------------------------------------------------------------------------------------
conv2_block2_out (Add)          (None, 56, 56, 256)  0
conv2_block1_out[0][0]
conv2_block2_3_conv[0][0]
----------------------------------------------------------------------------------------------------
conv2_block3_preact_bn (BatchNo (None, 56, 56, 256)  1024
conv2_block2_out[0][0]
----------------------------------------------------------------------------------------------------
conv2_block3_preact_relu (Activ (None, 56, 56, 256)  0
```

```
conv2_block3_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv2_block3_1_conv (Conv2D)    (None, 56, 56, 64)   16384
conv2_block3_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv2_block3_1_bn (BatchNormali (None, 56, 56, 64)   256
conv2_block3_1_conv[0][0]
__________________________________________________________________________________
__________________
conv2_block3_1_relu (Activation (None, 56, 56, 64)   0
conv2_block3_1_bn[0][0]
__________________________________________________________________________________
__________________
conv2_block3_2_pad (ZeroPadding (None, 58, 58, 64)   0
conv2_block3_1_relu[0][0]
__________________________________________________________________________________
__________________
conv2_block3_2_conv (Conv2D)    (None, 28, 28, 64)   36864
conv2_block3_2_pad[0][0]
__________________________________________________________________________________
__________________
conv2_block3_2_bn (BatchNormali (None, 28, 28, 64)   256
conv2_block3_2_conv[0][0]
__________________________________________________________________________________
__________________
conv2_block3_2_relu (Activation (None, 28, 28, 64)   0
conv2_block3_2_bn[0][0]
__________________________________________________________________________________
__________________
max_pooling2d (MaxPooling2D)    (None, 28, 28, 256)  0
conv2_block2_out[0][0]
__________________________________________________________________________________
__________________
conv2_block3_3_conv (Conv2D)    (None, 28, 28, 256)  16640
conv2_block3_2_relu[0][0]
__________________________________________________________________________________
__________________
conv2_block3_out (Add)          (None, 28, 28, 256)  0
max_pooling2d[0][0]
conv2_block3_3_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block1_preact_bn (BatchNo (None, 28, 28, 256)  1024
conv2_block3_out[0][0]
__________________________________________________________________________________
__________________
```

```
conv3_block1_preact_relu (Activ (None, 28, 28, 256)  0
conv3_block1_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv3_block1_1_conv (Conv2D)    (None, 28, 28, 128)  32768
conv3_block1_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block1_1_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block1_1_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block1_1_relu (Activation (None, 28, 28, 128)  0
conv3_block1_1_bn[0][0]
__________________________________________________________________________________
__________________
conv3_block1_2_pad (ZeroPadding (None, 30, 30, 128)  0
conv3_block1_1_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block1_2_conv (Conv2D)    (None, 28, 28, 128)  147456
conv3_block1_2_pad[0][0]
__________________________________________________________________________________
__________________
conv3_block1_2_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block1_2_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block1_2_relu (Activation (None, 28, 28, 128)  0
conv3_block1_2_bn[0][0]
__________________________________________________________________________________
__________________
conv3_block1_0_conv (Conv2D)    (None, 28, 28, 512)  131584
conv3_block1_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block1_3_conv (Conv2D)    (None, 28, 28, 512)  66048
conv3_block1_2_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block1_out (Add)          (None, 28, 28, 512)  0
conv3_block1_0_conv[0][0]
conv3_block1_3_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block2_preact_bn (BatchNo (None, 28, 28, 512)  2048
conv3_block1_out[0][0]
__________________________________________________________________________________
```

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------------------
conv3_block2_preact_relu (Activ (None, 28, 28, 512)  0
conv3_block2_preact_bn[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_1_conv (Conv2D)    (None, 28, 28, 128)  65536
conv3_block2_preact_relu[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_1_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block2_1_conv[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_1_relu (Activation (None, 28, 28, 128)  0
conv3_block2_1_bn[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_2_pad (ZeroPadding (None, 30, 30, 128)  0
conv3_block2_1_relu[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_2_conv (Conv2D)    (None, 28, 28, 128)  147456
conv3_block2_2_pad[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_2_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block2_2_conv[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_2_relu (Activation (None, 28, 28, 128)  0
conv3_block2_2_bn[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_3_conv (Conv2D)    (None, 28, 28, 512)  66048
conv3_block2_2_relu[0][0]
------------------------------------------------------------------------------
------------------
conv3_block2_out (Add)          (None, 28, 28, 512)  0
conv3_block1_out[0][0]
conv3_block2_3_conv[0][0]
------------------------------------------------------------------------------
------------------
conv3_block3_preact_bn (BatchNo (None, 28, 28, 512)  2048
conv3_block2_out[0][0]
------------------------------------------------------------------------------
------------------
conv3_block3_preact_relu (Activ (None, 28, 28, 512)  0
conv3_block3_preact_bn[0][0]
```

```
----------------------------------------------------------------------------------------------------
conv3_block3_1_conv (Conv2D)    (None, 28, 28, 128)  65536
conv3_block3_preact_relu[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_1_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block3_1_conv[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_1_relu (Activation (None, 28, 28, 128)  0
conv3_block3_1_bn[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_2_pad (ZeroPadding (None, 30, 30, 128)  0
conv3_block3_1_relu[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_2_conv (Conv2D)    (None, 28, 28, 128)  147456
conv3_block3_2_pad[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_2_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block3_2_conv[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_2_relu (Activation (None, 28, 28, 128)  0
conv3_block3_2_bn[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_3_conv (Conv2D)    (None, 28, 28, 512)  66048
conv3_block3_2_relu[0][0]
----------------------------------------------------------------------------------------------------
conv3_block3_out (Add)          (None, 28, 28, 512)  0
conv3_block2_out[0][0]
conv3_block3_3_conv[0][0]
----------------------------------------------------------------------------------------------------
conv3_block4_preact_bn (BatchNo (None, 28, 28, 512)  2048
conv3_block3_out[0][0]
----------------------------------------------------------------------------------------------------
conv3_block4_preact_relu (Activ (None, 28, 28, 512)  0
conv3_block4_preact_bn[0][0]
----------------------------------------------------------------------------------------------------
conv3_block4_1_conv (Conv2D)    (None, 28, 28, 128)  65536
```

```
conv3_block4_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block4_1_bn (BatchNormali (None, 28, 28, 128)  512
conv3_block4_1_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block4_1_relu (Activation (None, 28, 28, 128)  0
conv3_block4_1_bn[0][0]
__________________________________________________________________________________
__________________
conv3_block4_2_pad (ZeroPadding (None, 30, 30, 128)  0
conv3_block4_1_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block4_2_conv (Conv2D)    (None, 14, 14, 128)  147456
conv3_block4_2_pad[0][0]
__________________________________________________________________________________
__________________
conv3_block4_2_bn (BatchNormali (None, 14, 14, 128)  512
conv3_block4_2_conv[0][0]
__________________________________________________________________________________
__________________
conv3_block4_2_relu (Activation (None, 14, 14, 128)  0
conv3_block4_2_bn[0][0]
__________________________________________________________________________________
__________________
max_pooling2d_1 (MaxPooling2D)  (None, 14, 14, 512)  0
conv3_block3_out[0][0]
__________________________________________________________________________________
__________________
conv3_block4_3_conv (Conv2D)    (None, 14, 14, 512)  66048
conv3_block4_2_relu[0][0]
__________________________________________________________________________________
__________________
conv3_block4_out (Add)          (None, 14, 14, 512)  0
max_pooling2d_1[0][0]
conv3_block4_3_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block1_preact_bn (BatchNo (None, 14, 14, 512)  2048
conv3_block4_out[0][0]
__________________________________________________________________________________
__________________
conv4_block1_preact_relu (Activ (None, 14, 14, 512)  0
conv4_block1_preact_bn[0][0]
__________________________________________________________________________________
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```

```
conv4_block1_1_conv (Conv2D)    (None, 14, 14, 256)  131072
conv4_block1_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block1_1_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block1_1_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block1_1_relu (Activation (None, 14, 14, 256)  0
conv4_block1_1_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block1_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block1_1_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block1_2_conv (Conv2D)    (None, 14, 14, 256)  589824
conv4_block1_2_pad[0][0]
__________________________________________________________________________________
__________________
conv4_block1_2_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block1_2_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block1_2_relu (Activation (None, 14, 14, 256)  0
conv4_block1_2_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block1_0_conv (Conv2D)    (None, 14, 14, 1024) 525312
conv4_block1_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block1_3_conv (Conv2D)    (None, 14, 14, 1024) 263168
conv4_block1_2_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block1_out (Add)          (None, 14, 14, 1024) 0
conv4_block1_0_conv[0][0]
conv4_block1_3_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block2_preact_bn (BatchNo (None, 14, 14, 1024) 4096
conv4_block1_out[0][0]
__________________________________________________________________________________
__________________
conv4_block2_preact_relu (Activ (None, 14, 14, 1024) 0
conv4_block2_preact_bn[0][0]
__________________________________________________________________________________
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------------------
conv4_block2_1_conv (Conv2D)    (None, 14, 14, 256)  262144
conv4_block2_preact_relu[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_1_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block2_1_conv[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_1_relu (Activation (None, 14, 14, 256)  0
conv4_block2_1_bn[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block2_1_relu[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_2_conv (Conv2D)    (None, 14, 14, 256)  589824
conv4_block2_2_pad[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_2_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block2_2_conv[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_2_relu (Activation (None, 14, 14, 256)  0
conv4_block2_2_bn[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_3_conv (Conv2D)    (None, 14, 14, 1024) 263168
conv4_block2_2_relu[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block2_out (Add)          (None, 14, 14, 1024) 0
conv4_block1_out[0][0]
conv4_block2_3_conv[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block3_preact_bn (BatchNo (None, 14, 14, 1024) 4096
conv4_block2_out[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block3_preact_relu (Activ (None, 14, 14, 1024) 0
conv4_block3_preact_bn[0][0]
------------------------------------------------------------------------------------
------------------
conv4_block3_1_conv (Conv2D)    (None, 14, 14, 256)  262144
conv4_block3_preact_relu[0][0]
```

```
----------------------------------------------------------------------------------------------------
conv4_block3_1_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block3_1_conv[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_1_relu (Activation (None, 14, 14, 256)  0
conv4_block3_1_bn[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block3_1_relu[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_2_conv (Conv2D)    (None, 14, 14, 256)  589824
conv4_block3_2_pad[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_2_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block3_2_conv[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_2_relu (Activation (None, 14, 14, 256)  0
conv4_block3_2_bn[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_3_conv (Conv2D)    (None, 14, 14, 1024) 263168
conv4_block3_2_relu[0][0]
----------------------------------------------------------------------------------------------------
conv4_block3_out (Add)          (None, 14, 14, 1024) 0
conv4_block2_out[0][0]
conv4_block3_3_conv[0][0]
----------------------------------------------------------------------------------------------------
conv4_block4_preact_bn (BatchNo (None, 14, 14, 1024) 4096
conv4_block3_out[0][0]
----------------------------------------------------------------------------------------------------
conv4_block4_preact_relu (Activ (None, 14, 14, 1024) 0
conv4_block4_preact_bn[0][0]
----------------------------------------------------------------------------------------------------
conv4_block4_1_conv (Conv2D)    (None, 14, 14, 256)  262144
conv4_block4_preact_relu[0][0]
----------------------------------------------------------------------------------------------------
conv4_block4_1_bn (BatchNormali (None, 14, 14, 256)  1024
```

```
conv4_block4_1_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block4_1_relu (Activation (None, 14, 14, 256)  0
conv4_block4_1_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block4_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block4_1_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block4_2_conv (Conv2D)    (None, 14, 14, 256)  589824
conv4_block4_2_pad[0][0]
__________________________________________________________________________________
__________________
conv4_block4_2_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block4_2_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block4_2_relu (Activation (None, 14, 14, 256)  0
conv4_block4_2_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block4_3_conv (Conv2D)    (None, 14, 14, 1024) 263168
conv4_block4_2_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block4_out (Add)          (None, 14, 14, 1024) 0
conv4_block3_out[0][0]
conv4_block4_3_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block5_preact_bn (BatchNo (None, 14, 14, 1024) 4096
conv4_block4_out[0][0]
__________________________________________________________________________________
__________________
conv4_block5_preact_relu (Activ (None, 14, 14, 1024) 0
conv4_block5_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block5_1_conv (Conv2D)    (None, 14, 14, 256)  262144
conv4_block5_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block5_1_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block5_1_conv[0][0]
__________________________________________________________________________________
__________________
```

```
conv4_block5_1_relu (Activation (None, 14, 14, 256)  0
conv4_block5_1_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block5_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block5_1_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block5_2_conv (Conv2D)    (None, 14, 14, 256)  589824
conv4_block5_2_pad[0][0]
__________________________________________________________________________________
__________________
conv4_block5_2_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block5_2_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block5_2_relu (Activation (None, 14, 14, 256)  0
conv4_block5_2_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block5_3_conv (Conv2D)    (None, 14, 14, 1024) 263168
conv4_block5_2_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block5_out (Add)          (None, 14, 14, 1024) 0
conv4_block4_out[0][0]
conv4_block5_3_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block6_preact_bn (BatchNo (None, 14, 14, 1024) 4096
conv4_block5_out[0][0]
__________________________________________________________________________________
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conv4_block6_preact_relu (Activ (None, 14, 14, 1024) 0
conv4_block6_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv4_block6_1_conv (Conv2D)    (None, 14, 14, 256)  262144
conv4_block6_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv4_block6_1_bn (BatchNormali (None, 14, 14, 256)  1024
conv4_block6_1_conv[0][0]
__________________________________________________________________________________
__________________
conv4_block6_1_relu (Activation (None, 14, 14, 256)  0
conv4_block6_1_bn[0][0]
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```

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conv4_block6_2_pad (ZeroPadding (None, 16, 16, 256)  0
conv4_block6_1_relu[0][0]
------------------------------------------------------------------------------
------------------
conv4_block6_2_conv (Conv2D)    (None, 7, 7, 256)    589824
conv4_block6_2_pad[0][0]
------------------------------------------------------------------------------
------------------
conv4_block6_2_bn (BatchNormali (None, 7, 7, 256)    1024
conv4_block6_2_conv[0][0]
------------------------------------------------------------------------------
------------------
conv4_block6_2_relu (Activation (None, 7, 7, 256)    0
conv4_block6_2_bn[0][0]
------------------------------------------------------------------------------
------------------
max_pooling2d_2 (MaxPooling2D)  (None, 7, 7, 1024)   0
conv4_block5_out[0][0]
------------------------------------------------------------------------------
------------------
conv4_block6_3_conv (Conv2D)    (None, 7, 7, 1024)   263168
conv4_block6_2_relu[0][0]
------------------------------------------------------------------------------
------------------
conv4_block6_out (Add)          (None, 7, 7, 1024)   0
max_pooling2d_2[0][0]
conv4_block6_3_conv[0][0]
------------------------------------------------------------------------------
------------------
conv5_block1_preact_bn (BatchNo (None, 7, 7, 1024)   4096
conv4_block6_out[0][0]
------------------------------------------------------------------------------
------------------
conv5_block1_preact_relu (Activ (None, 7, 7, 1024)   0
conv5_block1_preact_bn[0][0]
------------------------------------------------------------------------------
------------------
conv5_block1_1_conv (Conv2D)    (None, 7, 7, 512)    524288
conv5_block1_preact_relu[0][0]
------------------------------------------------------------------------------
------------------
conv5_block1_1_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block1_1_conv[0][0]
------------------------------------------------------------------------------
------------------
conv5_block1_1_relu (Activation (None, 7, 7, 512)    0
conv5_block1_1_bn[0][0]
```

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__________________________________________________________________________________
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conv5_block1_2_pad (ZeroPadding (None, 9, 9, 512)    0
conv5_block1_1_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block1_2_conv (Conv2D)    (None, 7, 7, 512)    2359296
conv5_block1_2_pad[0][0]
__________________________________________________________________________________
__________________
conv5_block1_2_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block1_2_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block1_2_relu (Activation (None, 7, 7, 512)    0
conv5_block1_2_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block1_0_conv (Conv2D)    (None, 7, 7, 2048)   2099200
conv5_block1_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block1_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624
conv5_block1_2_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block1_out (Add)          (None, 7, 7, 2048)   0
conv5_block1_0_conv[0][0]
conv5_block1_3_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block2_preact_bn (BatchNo (None, 7, 7, 2048)   8192
conv5_block1_out[0][0]
__________________________________________________________________________________
__________________
conv5_block2_preact_relu (Activ (None, 7, 7, 2048)   0
conv5_block2_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block2_1_conv (Conv2D)    (None, 7, 7, 512)    1048576
conv5_block2_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block2_1_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block2_1_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block2_1_relu (Activation (None, 7, 7, 512)    0
```

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conv5_block2_1_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block2_2_pad (ZeroPadding (None, 9, 9, 512)    0
conv5_block2_1_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block2_2_conv (Conv2D)    (None, 7, 7, 512)    2359296
conv5_block2_2_pad[0][0]
__________________________________________________________________________________
__________________
conv5_block2_2_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block2_2_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block2_2_relu (Activation (None, 7, 7, 512)    0
conv5_block2_2_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block2_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624
conv5_block2_2_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block2_out (Add)          (None, 7, 7, 2048)   0
conv5_block1_out[0][0]
conv5_block2_3_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block3_preact_bn (BatchNo (None, 7, 7, 2048)   8192
conv5_block2_out[0][0]
__________________________________________________________________________________
__________________
conv5_block3_preact_relu (Activ (None, 7, 7, 2048)   0
conv5_block3_preact_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block3_1_conv (Conv2D)    (None, 7, 7, 512)    1048576
conv5_block3_preact_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block3_1_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block3_1_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block3_1_relu (Activation (None, 7, 7, 512)    0
conv5_block3_1_bn[0][0]
__________________________________________________________________________________
__________________
```

```
conv5_block3_2_pad (ZeroPadding (None, 9, 9, 512)    0
conv5_block3_1_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block3_2_conv (Conv2D)    (None, 7, 7, 512)    2359296
conv5_block3_2_pad[0][0]
__________________________________________________________________________________
__________________
conv5_block3_2_bn (BatchNormali (None, 7, 7, 512)    2048
conv5_block3_2_conv[0][0]
__________________________________________________________________________________
__________________
conv5_block3_2_relu (Activation (None, 7, 7, 512)    0
conv5_block3_2_bn[0][0]
__________________________________________________________________________________
__________________
conv5_block3_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624
conv5_block3_2_relu[0][0]
__________________________________________________________________________________
__________________
conv5_block3_out (Add)          (None, 7, 7, 2048)   0
conv5_block2_out[0][0]
conv5_block3_3_conv[0][0]
__________________________________________________________________________________
__________________
post_bn (BatchNormalization)    (None, 7, 7, 2048)   8192
conv5_block3_out[0][0]
__________________________________________________________________________________
__________________
post_relu (Activation)          (None, 7, 7, 2048)   0           post_bn[0][0]
==================================================================================
==================
Total params: 23,564,800
Trainable params: 0
Non-trainable params: 23,564,800
__________________________________________________________________________________
__________________
None
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
resnet50v2 (Model)           (None, 7, 7, 2048)        23564800
_________________________________________________________________
average_pooling2d (AveragePo (None, 1, 1, 2048)        0
_________________________________________________________________
flatten (Flatten)            (None, 2048)              0
_________________________________________________________________
```

```
dropout (Dropout)            (None, 2048)              0
_________________________________________________________________
dense (Dense)                (None, 256)               524544
_________________________________________________________________
dropout_1 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_1 (Dense)              (None, 4)                 1028
=================================================================
Total params: 24,090,372
Trainable params: 525,572
Non-trainable params: 23,564,800
_________________________________________________________________
```

[5]:
```python
# FIT MODEL
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import ModelCheckpoint, LearningRateScheduler
from tensorflow.keras.callbacks import ReduceLROnPlateau

print(len(train_batches))
print(len(valid_batches))

STEP_SIZE_TRAIN=train_batches.n//train_batches.batch_size
STEP_SIZE_VALID=valid_batches.n//valid_batches.batch_size


def lr_schedule(epoch):
    """Learning Rate Schedule

    Learning rate is scheduled to be reduced after 80, 120, 160, 180 epochs.
    Called automatically every epoch as part of callbacks during training.

    # Arguments
        epoch (int): The number of epochs

    # Returns
        lr (float32): learning rate
    """
    lr = 1e-3
    if epoch > 180:
        lr *= 0.5e-3
    elif epoch > 160:
        lr *= 1e-3
    elif epoch > 120:
        lr *= 1e-2
    elif epoch > 80:
        lr *= 1e-1
    print('Learning rate: ', lr)
```

```
    return lr


# Prepare callbacks for model saving and for learning rate adjustment.
checkpoint = ModelCheckpoint(filepath=DATA_LIST,
                             monitor='val_acc',
                             verbose=1,
                             save_best_only=True)

lr_scheduler = LearningRateScheduler(lr_schedule)

lr_reducer = ReduceLROnPlateau(factor=np.sqrt(0.1),
                               cooldown=0,
                               patience=5,
                               min_lr=0.5e-6)

callbacks = [lr_reducer, lr_scheduler]

# raise NotImplementedError("Use the model.fit function to train your network")
# covid_model.compile(optimizer='adam', loss=tf.keras.losses.
 ↪CategoricalCrossentropy(from_logits=False), metrics=['accuracy'])
covid_model.compile(optimizer=Adam(learning_rate=lr_schedule(0)), loss=tf.keras.
 ↪losses.CategoricalCrossentropy(from_logits=False), metrics=['accuracy'])
history = None

with tf.device("GPU:0"):
    history = covid_model.fit_generator(generator=train_batches,
                                steps_per_epoch=STEP_SIZE_TRAIN,
                                epochs=100,
                                validation_data=(valid_batches),
                                validation_steps=STEP_SIZE_VALID,
                                callbacks=callbacks)
```

```
22
6
Learning rate:  0.001
WARNING:tensorflow:From <ipython-input-5-aa9b0faf9702>:64: Model.fit_generator
(from tensorflow.python.keras.engine.training) is deprecated and will be removed
in a future version.
Instructions for updating:
Please use Model.fit, which supports generators.
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']

C:\Users\tanzi\Anaconda3\lib\site-
packages\keras_preprocessing\image\image_data_generator.py:716: UserWarning:
```

```
This ImageDataGenerator specifies `featurewise_center`, but it hasn't been fit
on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
C:\Users\tanzi\Anaconda3\lib\site-
packages\keras_preprocessing\image\image_data_generator.py:735: UserWarning:
This ImageDataGenerator specifies `zca_whitening`, but it hasn't been fit on any
training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '

WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
Train for 21 steps, validate for 5 steps
Learning rate:  0.001
Epoch 1/100

C:\Users\tanzi\Anaconda3\lib\site-
packages\keras_preprocessing\image\image_data_generator.py:716: UserWarning:
This ImageDataGenerator specifies `featurewise_center`, but it hasn't been fit
on any training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '
C:\Users\tanzi\Anaconda3\lib\site-
packages\keras_preprocessing\image\image_data_generator.py:735: UserWarning:
This ImageDataGenerator specifies `zca_whitening`, but it hasn't been fit on any
training data. Fit it first by calling `.fit(numpy_data)`.
  warnings.warn('This ImageDataGenerator specifies '

21/21 [==============================] - 10s 484ms/step - loss: 1.2680 -
accuracy: 0.4563 - val_loss: 2.3497 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 2/100
21/21 [==============================] - 6s 281ms/step - loss: 1.0186 -
accuracy: 0.5388 - val_loss: 1.6810 - val_accuracy: 0.4600
Learning rate:  0.001
Epoch 3/100
21/21 [==============================] - 6s 280ms/step - loss: 0.9670 -
accuracy: 0.5583 - val_loss: 1.6275 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 4/100
21/21 [==============================] - 6s 293ms/step - loss: 0.8816 -
accuracy: 0.6796 - val_loss: 1.5871 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 5/100
21/21 [==============================] - 6s 293ms/step - loss: 0.8912 -
accuracy: 0.6262 - val_loss: 1.7144 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 6/100
21/21 [==============================] - 6s 293ms/step - loss: 0.7269 -
```

```
accuracy: 0.7286 - val_loss: 1.8195 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 7/100
21/21 [==============================] - 6s 282ms/step - loss: 0.7497 -
accuracy: 0.6553 - val_loss: 2.1060 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 8/100
21/21 [==============================] - 6s 277ms/step - loss: 0.8370 -
accuracy: 0.6893 - val_loss: 1.7917 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 9/100
21/21 [==============================] - 6s 286ms/step - loss: 0.7720 -
accuracy: 0.6893 - val_loss: 2.1225 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 10/100
21/21 [==============================] - 6s 285ms/step - loss: 0.7681 -
accuracy: 0.6650 - val_loss: 1.9455 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 11/100
21/21 [==============================] - 6s 298ms/step - loss: 0.7834 -
accuracy: 0.6762 - val_loss: 2.0948 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 12/100
21/21 [==============================] - 7s 333ms/step - loss: 0.6786 -
accuracy: 0.7379 - val_loss: 2.3389 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 13/100
21/21 [==============================] - 7s 314ms/step - loss: 0.7501 -
accuracy: 0.6796 - val_loss: 2.4362 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 14/100
21/21 [==============================] - 6s 290ms/step - loss: 0.6270 -
accuracy: 0.7476 - val_loss: 2.2879 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 15/100
21/21 [==============================] - 6s 307ms/step - loss: 0.6254 -
accuracy: 0.7184 - val_loss: 3.1163 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 16/100
21/21 [==============================] - 6s 286ms/step - loss: 0.6128 -
accuracy: 0.7476 - val_loss: 2.4645 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 17/100
21/21 [==============================] - 7s 314ms/step - loss: 0.5928 -
accuracy: 0.7427 - val_loss: 2.6771 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 18/100
21/21 [==============================] - 7s 321ms/step - loss: 0.5907 -
```

```
accuracy: 0.7429 - val_loss: 2.1543 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 19/100
21/21 [==============================] - 6s 289ms/step - loss: 0.6386 -
accuracy: 0.7136 - val_loss: 2.1171 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 20/100
21/21 [==============================] - 6s 285ms/step - loss: 0.6523 -
accuracy: 0.7136 - val_loss: 3.4484 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 21/100
21/21 [==============================] - 6s 277ms/step - loss: 0.7657 -
accuracy: 0.6893 - val_loss: 3.3510 - val_accuracy: 0.2600
Learning rate:  0.001
Epoch 22/100
21/21 [==============================] - 6s 291ms/step - loss: 0.6553 -
accuracy: 0.7184 - val_loss: 2.5376 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 23/100
21/21 [==============================] - 6s 303ms/step - loss: 0.6477 -
accuracy: 0.7184 - val_loss: 2.9789 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 24/100
21/21 [==============================] - 6s 305ms/step - loss: 0.5501 -
accuracy: 0.7573 - val_loss: 3.0626 - val_accuracy: 0.2600
Learning rate:  0.001
Epoch 25/100
21/21 [==============================] - 6s 292ms/step - loss: 0.6325 -
accuracy: 0.7379 - val_loss: 2.5004 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 26/100
21/21 [==============================] - 6s 294ms/step - loss: 0.6263 -
accuracy: 0.7524 - val_loss: 2.7615 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 27/100
21/21 [==============================] - 6s 283ms/step - loss: 0.6911 -
accuracy: 0.6990 - val_loss: 1.4695 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 28/100
21/21 [==============================] - 6s 280ms/step - loss: 0.6430 -
accuracy: 0.7136 - val_loss: 1.6927 - val_accuracy: 0.5200
Learning rate:  0.001
Epoch 29/100
21/21 [==============================] - 6s 290ms/step - loss: 0.6328 -
accuracy: 0.7143 - val_loss: 2.1378 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 30/100
21/21 [==============================] - 6s 289ms/step - loss: 0.5315 -
```

```
accuracy: 0.7767 - val_loss: 3.4603 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 31/100
21/21 [==============================] - 6s 278ms/step - loss: 0.5497 -
accuracy: 0.7864 - val_loss: 2.6478 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 32/100
21/21 [==============================] - 6s 294ms/step - loss: 0.5707 -
accuracy: 0.7718 - val_loss: 2.9752 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 33/100
21/21 [==============================] - 6s 290ms/step - loss: 0.6012 -
accuracy: 0.7476 - val_loss: 1.9118 - val_accuracy: 0.5400
Learning rate:  0.001
Epoch 34/100
21/21 [==============================] - 6s 298ms/step - loss: 0.5469 -
accuracy: 0.7718 - val_loss: 1.3733 - val_accuracy: 0.5000
Learning rate:  0.001
Epoch 35/100
21/21 [==============================] - 6s 290ms/step - loss: 0.5139 -
accuracy: 0.7961 - val_loss: 1.8940 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 36/100
21/21 [==============================] - 6s 291ms/step - loss: 0.6196 -
accuracy: 0.7379 - val_loss: 1.3698 - val_accuracy: 0.5400
Learning rate:  0.001
Epoch 37/100
21/21 [==============================] - 6s 276ms/step - loss: 0.5623 -
accuracy: 0.7427 - val_loss: 1.4876 - val_accuracy: 0.6000
Learning rate:  0.001
Epoch 38/100
21/21 [==============================] - 6s 283ms/step - loss: 0.5045 -
accuracy: 0.7767 - val_loss: 1.6670 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 39/100
21/21 [==============================] - 6s 279ms/step - loss: 0.5667 -
accuracy: 0.7330 - val_loss: 1.5689 - val_accuracy: 0.4600
Learning rate:  0.001
Epoch 40/100
21/21 [==============================] - 6s 282ms/step - loss: 0.5825 -
accuracy: 0.7184 - val_loss: 1.8555 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 41/100
21/21 [==============================] - 6s 282ms/step - loss: 0.4958 -
accuracy: 0.8107 - val_loss: 2.1339 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 42/100
21/21 [==============================] - 6s 283ms/step - loss: 0.5324 -
```

```
accuracy: 0.7621 - val_loss: 1.8467 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 43/100
21/21 [==============================] - 6s 284ms/step - loss: 0.5407 -
accuracy: 0.8010 - val_loss: 2.7070 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 44/100
21/21 [==============================] - 6s 284ms/step - loss: 0.5920 -
accuracy: 0.7330 - val_loss: 2.5445 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 45/100
21/21 [==============================] - 6s 292ms/step - loss: 0.5838 -
accuracy: 0.7379 - val_loss: 2.2987 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 46/100
21/21 [==============================] - 6s 290ms/step - loss: 0.5620 -
accuracy: 0.7379 - val_loss: 1.9059 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 47/100
21/21 [==============================] - 6s 291ms/step - loss: 0.5338 -
accuracy: 0.7913 - val_loss: 1.9330 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 48/100
21/21 [==============================] - 6s 276ms/step - loss: 0.5227 -
accuracy: 0.7816 - val_loss: 2.1342 - val_accuracy: 0.4400
Learning rate:  0.001
Epoch 49/100
21/21 [==============================] - 6s 301ms/step - loss: 0.5417 -
accuracy: 0.7961 - val_loss: 1.8819 - val_accuracy: 0.2800
Learning rate:  0.001
Epoch 50/100
21/21 [==============================] - 6s 291ms/step - loss: 0.5754 -
accuracy: 0.7718 - val_loss: 1.5026 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 51/100
21/21 [==============================] - 6s 286ms/step - loss: 0.5629 -
accuracy: 0.7718 - val_loss: 2.1450 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 52/100
21/21 [==============================] - 6s 298ms/step - loss: 0.5953 -
accuracy: 0.7573 - val_loss: 1.4009 - val_accuracy: 0.5000
Learning rate:  0.001
Epoch 53/100
21/21 [==============================] - 6s 303ms/step - loss: 0.5399 -
accuracy: 0.7427 - val_loss: 1.7826 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 54/100
21/21 [==============================] - 7s 312ms/step - loss: 0.5530 -
```

```
accuracy: 0.7476 - val_loss: 2.1585 - val_accuracy: 0.3000
Learning rate:  0.001
Epoch 55/100
21/21 [==============================] - 7s 314ms/step - loss: 0.4280 -
accuracy: 0.7961 - val_loss: 2.5170 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 56/100
21/21 [==============================] - 6s 308ms/step - loss: 0.4653 -
accuracy: 0.8204 - val_loss: 2.1974 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 57/100
21/21 [==============================] - 6s 292ms/step - loss: 0.5216 -
accuracy: 0.7864 - val_loss: 2.1145 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 58/100
21/21 [==============================] - 6s 306ms/step - loss: 0.4489 -
accuracy: 0.8350 - val_loss: 1.9311 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 59/100
21/21 [==============================] - 6s 288ms/step - loss: 0.4774 -
accuracy: 0.8107 - val_loss: 2.1155 - val_accuracy: 0.3800
Learning rate:  0.001
Epoch 60/100
21/21 [==============================] - 6s 302ms/step - loss: 0.4595 -
accuracy: 0.8107 - val_loss: 2.5238 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 61/100
21/21 [==============================] - 6s 293ms/step - loss: 0.5574 -
accuracy: 0.7767 - val_loss: 1.6849 - val_accuracy: 0.4600
Learning rate:  0.001
Epoch 62/100
21/21 [==============================] - 6s 305ms/step - loss: 0.5871 -
accuracy: 0.7864 - val_loss: 2.2173 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 63/100
21/21 [==============================] - 6s 307ms/step - loss: 0.4858 -
accuracy: 0.7864 - val_loss: 1.8804 - val_accuracy: 0.4400
Learning rate:  0.001
Epoch 64/100
21/21 [==============================] - 7s 311ms/step - loss: 0.5215 -
accuracy: 0.7864 - val_loss: 1.6845 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 65/100
21/21 [==============================] - 6s 301ms/step - loss: 0.4968 -
accuracy: 0.7816 - val_loss: 1.9405 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 66/100
21/21 [==============================] - 6s 295ms/step - loss: 0.5638 -
```

```
accuracy: 0.7767 - val_loss: 1.7509 - val_accuracy: 0.4600
Learning rate:  0.001
Epoch 67/100
21/21 [==============================] - 6s 287ms/step - loss: 0.5070 -
accuracy: 0.7621 - val_loss: 1.2299 - val_accuracy: 0.5400
Learning rate:  0.001
Epoch 68/100
21/21 [==============================] - 6s 286ms/step - loss: 0.4842 -
accuracy: 0.8252 - val_loss: 1.4440 - val_accuracy: 0.4800
Learning rate:  0.001
Epoch 69/100
21/21 [==============================] - 6s 291ms/step - loss: 0.4136 -
accuracy: 0.7913 - val_loss: 1.6261 - val_accuracy: 0.4400
Learning rate:  0.001
Epoch 70/100
21/21 [==============================] - 6s 282ms/step - loss: 0.4662 -
accuracy: 0.8107 - val_loss: 1.8448 - val_accuracy: 0.5600
Learning rate:  0.001
Epoch 71/100
21/21 [==============================] - 6s 293ms/step - loss: 0.5035 -
accuracy: 0.8058 - val_loss: 1.5048 - val_accuracy: 0.5000
Learning rate:  0.001
Epoch 72/100
21/21 [==============================] - 6s 293ms/step - loss: 0.5054 -
accuracy: 0.7961 - val_loss: 2.3159 - val_accuracy: 0.3400
Learning rate:  0.001
Epoch 73/100
21/21 [==============================] - 6s 286ms/step - loss: 0.4563 -
accuracy: 0.8107 - val_loss: 2.2962 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 74/100
21/21 [==============================] - 6s 285ms/step - loss: 0.5093 -
accuracy: 0.7913 - val_loss: 2.1430 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 75/100
21/21 [==============================] - 6s 283ms/step - loss: 0.4612 -
accuracy: 0.8058 - val_loss: 1.6153 - val_accuracy: 0.4000
Learning rate:  0.001
Epoch 76/100
21/21 [==============================] - 6s 282ms/step - loss: 0.5001 -
accuracy: 0.7718 - val_loss: 2.0796 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 77/100
21/21 [==============================] - 6s 288ms/step - loss: 0.4559 -
accuracy: 0.7961 - val_loss: 1.6331 - val_accuracy: 0.3600
Learning rate:  0.001
Epoch 78/100
21/21 [==============================] - 6s 293ms/step - loss: 0.4902 -
```

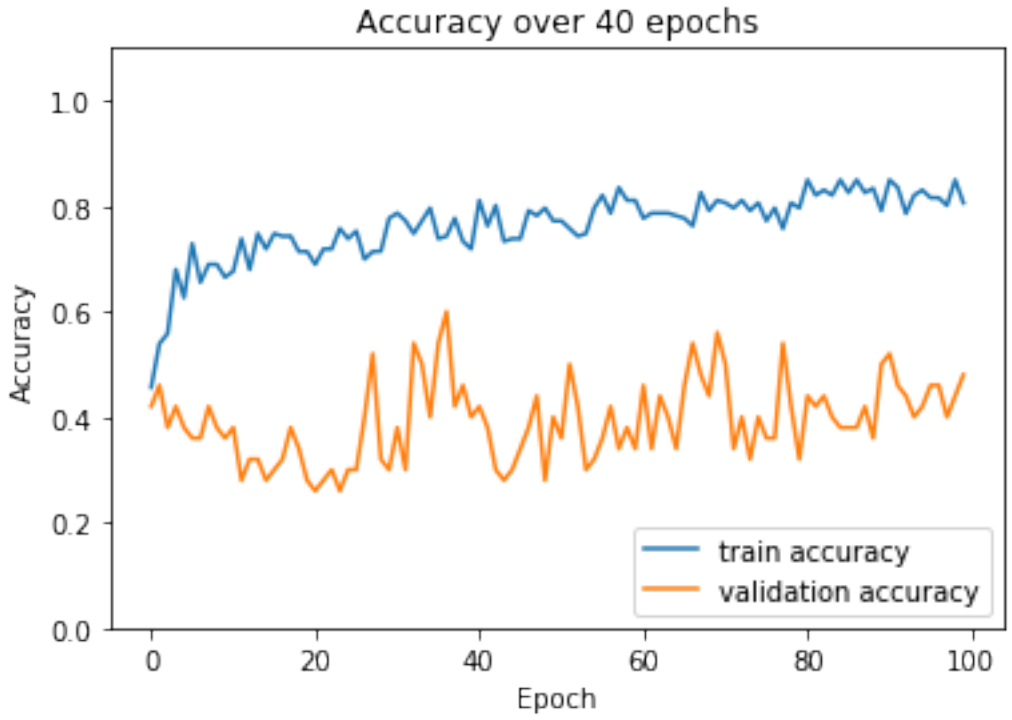
```
accuracy: 0.7573 - val_loss: 1.6944 - val_accuracy: 0.5400
Learning rate:  0.001
Epoch 79/100
21/21 [==============================] - 6s 289ms/step - loss: 0.4301 -
accuracy: 0.8058 - val_loss: 1.7243 - val_accuracy: 0.4200
Learning rate:  0.001
Epoch 80/100
21/21 [==============================] - 6s 294ms/step - loss: 0.4979 -
accuracy: 0.7961 - val_loss: 2.1791 - val_accuracy: 0.3200
Learning rate:  0.001
Epoch 81/100
21/21 [==============================] - 6s 293ms/step - loss: 0.4256 -
accuracy: 0.8495 - val_loss: 1.5680 - val_accuracy: 0.4400
Learning rate:  0.0001
Epoch 82/100
21/21 [==============================] - 6s 296ms/step - loss: 0.4400 -
accuracy: 0.8204 - val_loss: 1.5892 - val_accuracy: 0.4200
Learning rate:  0.0001
Epoch 83/100
21/21 [==============================] - 6s 295ms/step - loss: 0.4048 -
accuracy: 0.8301 - val_loss: 1.8898 - val_accuracy: 0.4400
Learning rate:  0.0001
Epoch 84/100
21/21 [==============================] - 6s 303ms/step - loss: 0.3887 -
accuracy: 0.8204 - val_loss: 1.8842 - val_accuracy: 0.4000
Learning rate:  0.0001
Epoch 85/100
21/21 [==============================] - 6s 285ms/step - loss: 0.3780 -
accuracy: 0.8495 - val_loss: 1.8367 - val_accuracy: 0.3800
Learning rate:  0.0001
Epoch 86/100
21/21 [==============================] - 6s 304ms/step - loss: 0.4077 -
accuracy: 0.8252 - val_loss: 1.9471 - val_accuracy: 0.3800
Learning rate:  0.0001
Epoch 87/100
21/21 [==============================] - 7s 310ms/step - loss: 0.3507 -
accuracy: 0.8495 - val_loss: 2.0925 - val_accuracy: 0.3800
Learning rate:  0.0001
Epoch 88/100
21/21 [==============================] - 6s 294ms/step - loss: 0.4026 -
accuracy: 0.8252 - val_loss: 1.6046 - val_accuracy: 0.4200
Learning rate:  0.0001
Epoch 89/100
21/21 [==============================] - 7s 314ms/step - loss: 0.4257 -
accuracy: 0.8333 - val_loss: 2.2097 - val_accuracy: 0.3600
Learning rate:  0.0001
Epoch 90/100
21/21 [==============================] - 6s 308ms/step - loss: 0.4372 -
```

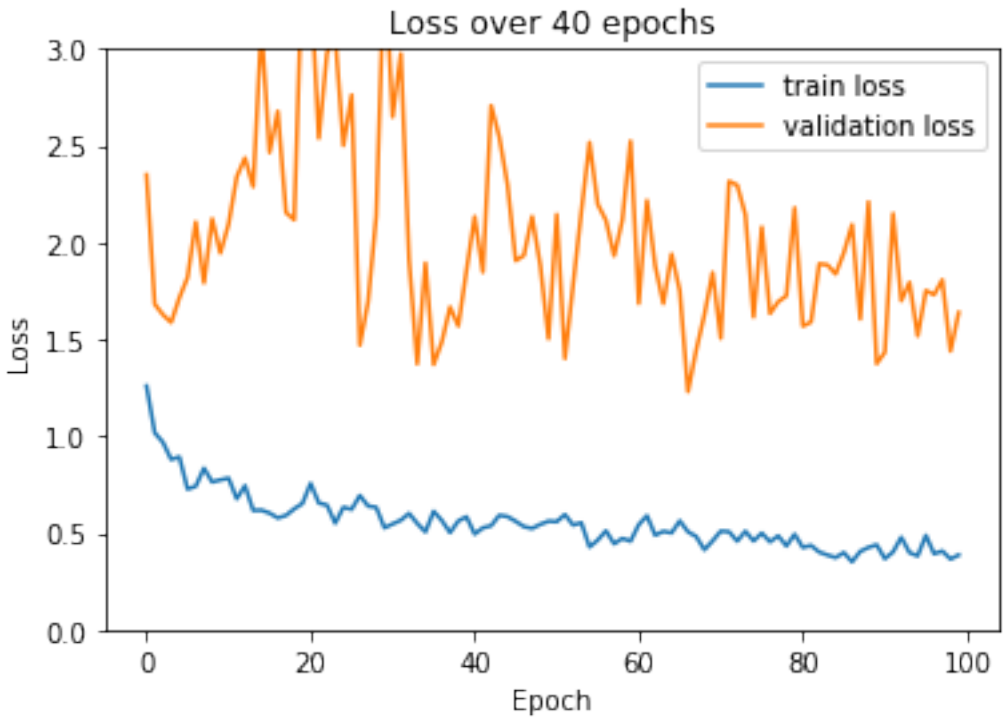
```
accuracy: 0.7913 - val_loss: 1.3744 - val_accuracy: 0.5000
Learning rate:  0.0001
Epoch 91/100
21/21 [==============================] - 7s 310ms/step - loss: 0.3802 -
accuracy: 0.8495 - val_loss: 1.4336 - val_accuracy: 0.5200
Learning rate:  0.0001
Epoch 92/100
21/21 [==============================] - 6s 294ms/step - loss: 0.4043 -
accuracy: 0.8350 - val_loss: 2.1497 - val_accuracy: 0.4600
Learning rate:  0.0001
Epoch 93/100
21/21 [==============================] - 6s 308ms/step - loss: 0.4781 -
accuracy: 0.7857 - val_loss: 1.6988 - val_accuracy: 0.4400
Learning rate:  0.0001
Epoch 94/100
21/21 [==============================] - 6s 300ms/step - loss: 0.3961 -
accuracy: 0.8204 - val_loss: 1.7940 - val_accuracy: 0.4000
Learning rate:  0.0001
Epoch 95/100
21/21 [==============================] - 6s 302ms/step - loss: 0.3903 -
accuracy: 0.8301 - val_loss: 1.5174 - val_accuracy: 0.4200
Learning rate:  0.0001
Epoch 96/100
21/21 [==============================] - 6s 290ms/step - loss: 0.4931 -
accuracy: 0.8155 - val_loss: 1.7518 - val_accuracy: 0.4600
Learning rate:  0.0001
Epoch 97/100
21/21 [==============================] - 6s 290ms/step - loss: 0.3907 -
accuracy: 0.8155 - val_loss: 1.7299 - val_accuracy: 0.4600
Learning rate:  0.0001
Epoch 98/100
21/21 [==============================] - 6s 288ms/step - loss: 0.4075 -
accuracy: 0.8010 - val_loss: 1.8073 - val_accuracy: 0.4000
Learning rate:  0.0001
Epoch 99/100
21/21 [==============================] - 6s 302ms/step - loss: 0.3690 -
accuracy: 0.8495 - val_loss: 1.4391 - val_accuracy: 0.4400
Learning rate:  0.0001
Epoch 100/100
21/21 [==============================] - 6s 304ms/step - loss: 0.3899 -
accuracy: 0.8058 - val_loss: 1.6383 - val_accuracy: 0.4800
```

[6]:
```python
import matplotlib.pyplot as plt

# raise NotImplementedError("Plot the accuracy and the loss during training")

# Accuracy over 40 Epochs
```

```
plt.figure()
plt.plot(history.history['accuracy'], label='train accuracy')
plt.plot(history.history['val_accuracy'], label = 'validation accuracy')
plt.title('Accuracy over 40 epochs')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.ylim([0, 1.1])
plt.legend(loc='lower right')

# Loss over 40 Epochs
plt.figure()
plt.plot(history.history['loss'], label='train loss')
plt.plot(history.history['val_loss'], label = 'validation loss')
plt.title('Loss over 40 epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.ylim([0, 3])
plt.legend(loc='upper right')
```

[6]: <matplotlib.legend.Legend at 0x21cf7cd0208>





[7]:
```
test_datagen = ImageDataGenerator(rescale=1. / 255)

eval_generator = test_datagen.
 ↪flow_from_directory(TEST_DIR,target_size=IMAGE_SIZE,
                                                    ␣
 ↪batch_size=1,shuffle=True,seed=42,class_mode="categorical")
eval_generator.reset()
print(len(eval_generator))
x = covid_model.evaluate_generator(eval_generator,steps = np.
 ↪ceil(len(eval_generator)),
                           use_multiprocessing = False,verbose = 1,workers=1)
print('Test loss:' , x[0])
print('Test accuracy:',x[1])
```

```
Found 36 images belonging to 4 classes.
36
WARNING:tensorflow:From <ipython-input-7-dedefa902e64>:8:
Model.evaluate_generator (from tensorflow.python.keras.engine.training) is
deprecated and will be removed in a future version.
Instructions for updating:
Please use Model.evaluate, which supports generators.
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
```

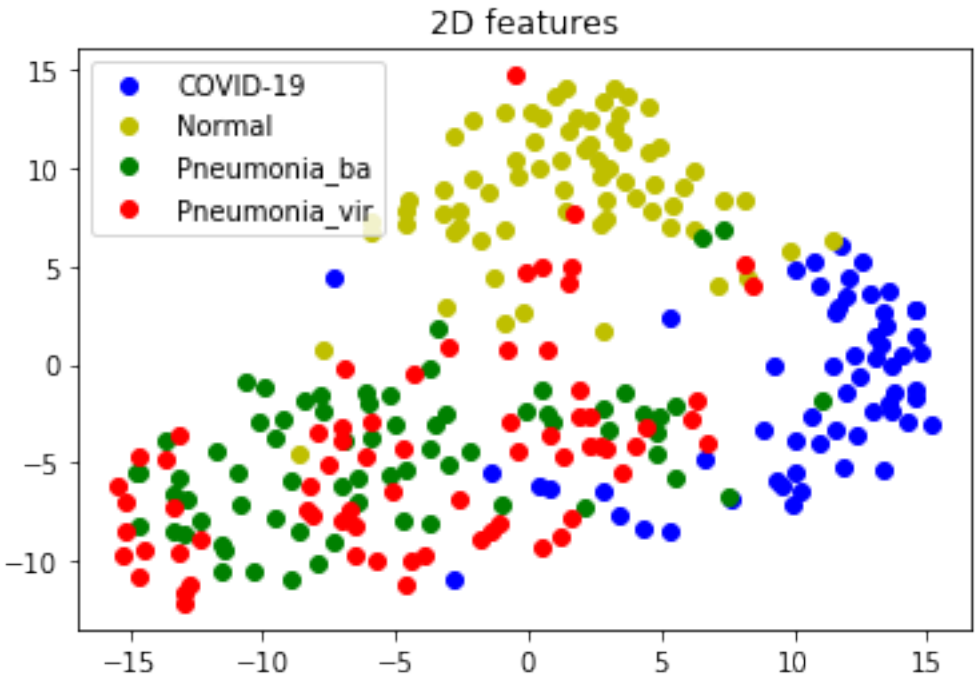
```
  ['...']
36/36 [==============================] - 1s 31ms/step - loss: 1.2718 - accuracy:
0.6111
Test loss: 1.2717785547073517
Test accuracy: 0.6111111
```

[8]:
```
from sklearn.manifold import TSNE

intermediate_layer_model = tf.keras.models.Model(inputs=covid_model.input,
                                         outputs=covid_model.get_layer('dense').
 ↪output)

tsne_eval_generator = test_datagen.
 ↪flow_from_directory(DATASET_PATH,target_size=IMAGE_SIZE,
                                                          ␣
 ↪batch_size=1,shuffle=False,seed=42,class_mode="categorical")

# raise NotImplementedError("Extract features from the tsne_data_generator and␣
 ↪fit a t-SNE model for the features,"
#                           "and plot the resulting 2D features of the four␣
 ↪classes.")

outputs = intermediate_layer_model.
 ↪predict_generator(tsne_eval_generator,270,verbose=1)
print(outputs.shape)
label = tsne_eval_generator.classes
features = TSNE(n_components=2).fit_transform(outputs)
print(features.shape)

covid_x = []
covid_y = []
normal_x = []
normal_y = []
pneumonia_bac_x = []
pneumonia_bac_y = []
pneumonia_vir_x = []
pneumonia_vir_y = []


plt.figure()
for index in range(len(features)):
    if label[index] == 0:
        # COVID: Blue
        covid_x.append(features[index, 0])
        covid_y.append(features[index, 1])
    elif label[index] == 1:
        # Normal: Yellow
```

```
        normal_x.append(features[index, 0])
        normal_y.append(features[index, 1])
    elif label[index] == 2:
        # Pneumonia_bac: Green
        pneumonia_bac_x.append(features[index, 0])
        pneumonia_bac_y.append(features[index, 1])
    else:
        # Pneumonia_vir: Red
        pneumonia_vir_x.append(features[index, 0])
        pneumonia_vir_y.append(features[index, 1])


plt.title('2D features')
plt.plot(covid_x, covid_y, 'bo', label="COVID-19")
plt.plot(normal_x, normal_y, 'yo', label="Normal")
plt.plot(pneumonia_bac_x, pneumonia_bac_y, 'go', label="Pneumonia_ba")
plt.plot(pneumonia_vir_x, pneumonia_vir_y, 'ro', label="Pneumonia_vir")
plt.legend(loc='upper left')
```

```
Found 270 images belonging to 4 classes.
WARNING:tensorflow:From <ipython-input-8-311fb591619f>:12:
Model.predict_generator (from tensorflow.python.keras.engine.training) is
deprecated and will be removed in a future version.
Instructions for updating:
Please use Model.predict, which supports generators.
270/270 [==============================] - 6s 23ms/step
(270, 256)
(270, 2)
```

[8]: <matplotlib.legend.Legend at 0x21d16529c88>


2D features
COVID-19
Normal
Pneumonia_ba
Pneumonia_vir
15
10
5
0
−5
−10
−15
−10
−5
0
5
10
15