In [1]:

```
"""
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"""

import os
import pandas as pd
import numpy as np
import zipfile
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import Model
from tensorflow.keras.layers import (
    Input, Conv2D, MaxPooling2D, Activation,
    AveragePooling2D, Flatten, BatchNormalization,
    Dense, Dropout, ZeroPadding2D, Add)
from keras.layers.merge import concatenate

from sklearn import metrics
import matplotlib.pyplot as plt
%matplotlib inline

TRAIN_PATH = "../input/covid19/"
EPOCHS = 100
BATCH_SIZE = 64
LEARNING_RATE = 0.001
INPUT_SIZE = (224, 224)

def load_data():
```

```
    """
    Loads input data from directory
    Arguments: None
    Returns: Train and val generator
    """

    train_datagen =  keras.preprocessing.image.ImageDataGenerator(validation_split=0.2) # set validation split

    train_generator = train_datagen.flow_from_directory(
        TRAIN_PATH,
        target_size=INPUT_SIZE,
        batch_size=BATCH_SIZE,
        shuffle=False,
        class_mode='categorical',
        subset='training') # set as training data

    validation_generator = train_datagen.flow_from_directory(
        TRAIN_PATH,
        target_size=INPUT_SIZE,
        batch_size=BATCH_SIZE,
        shuffle=False,
        class_mode='categorical',
        subset='validation') # set as validation data

    return train_generator, validation_generator


def identity_block(X, f, filters, stage, block):
    """
    The identity block is the block that has no conv layer at shortcut.
    Arguments:
```

```
    X       -- input tensor
    f       -- kernel size of middle conv layer at main path
    filters -- list of integers, the filters of 3 conv layer at main path
    stage   -- integer, current stage label, used for generating layer names
    block   -- 'a','b'..., current block label, used for generating layer names
Returns: Output tensor for the block.
"""

conv_name_base = 'res' + str(stage) + block + '_branch'
bn_name_base = 'bn' + str(stage) + block + '_branch'
f1, f2, f3 = filters

X_shortcut = X

X = Conv2D(filters=f1, kernel_size=(1, 1), strides=(1, 1), padding='valid', name=conv_name_base + '2a')(X)
X = BatchNormalization(axis=3, name=bn_name_base + '2a')(X)
X = Activation('relu')(X)

X = Conv2D(filters=f2, kernel_size=(f, f), strides=(1, 1), padding='same', name=conv_name_base + '2b')(X)
X = BatchNormalization(axis=3, name=bn_name_base + '2b')(X)
X = Activation('relu')(X)

X = Conv2D(filters=f3, kernel_size=(1, 1), strides=(1, 1), padding='valid', name=conv_name_base + '2c')(X)
X = BatchNormalization(axis=3, name=bn_name_base + '2c')(X)

X = Add()([X, X_shortcut])# Skip Connection
X = Activation('relu')(X)

return X
```

```
def convolutional_block(X, f, filters, stage, block, strides=(2,2)):
    """
    A block that has a conv layer at shortcut.
    Arguments:
        X       -- input tensor
        f       -- the kernel size of middle conv layer at main path
        filters -- list of integers, the filters of 3 conv layer at main path
        stage   -- integer, current stage label, used for generating layer names
        block   -- 'a','b'..., current block label, used for generating layer names
        strides -- strides for the first conv layer in the block.
    Returns: Output tensor for the block.
    """

    conv_name_base = 'res' + str(stage) + block + '_branch'
    bn_name_base = 'bn' + str(stage) + block + '_branch'

    f1, f2, f3 = filters

    X_shortcut = X

    X = Conv2D(filters=f1, kernel_size=(1, 1), strides=strides, padding='valid', name=conv_name_base + '2a')(X
)
    X = BatchNormalization(axis=3, name=bn_name_base + '2a')(X)
    X = Activation('relu')(X)

    X = Conv2D(filters=f2, kernel_size=(f, f), strides=(1, 1), padding='same', name=conv_name_base + '2b')(X)
    X = BatchNormalization(axis=3, name=bn_name_base + '2b')(X)
    X = Activation('relu')(X)

    X = Conv2D(filters=f3, kernel_size=(1, 1), strides=(1, 1), padding='valid', name=conv_name_base + '2c')(X)
    X = BatchNormalization(axis=3, name=bn_name_base + '2c')(X)
```

```
    X_shortcut = Conv2D(filters=f3, kernel_size=(1, 1), strides=strides, padding='valid', name=conv_name_base
+ '1')(X_shortcut)
    X_shortcut = BatchNormalization(axis=3, name=bn_name_base + '1')(X_shortcut)

    X = Add()([X, X_shortcut])
    X = Activation('relu')(X)

    return X


def load_model():
    """
    Creates a keras ResNet-50 model
    Arguments: None
    Returns: ResNet-50 Model
    """

    input_layer = Input(shape=(224, 224, 3))

    X = ZeroPadding2D((3, 3))(input_layer)

    X = Conv2D(64, (7, 7), strides=(2, 2), name='conv1')(X)
    X = BatchNormalization(axis=3, name='bn_conv1')(X)
    X = Activation('relu')(X)
    X = MaxPooling2D((3, 3), strides=(2, 2))(X)

    X = convolutional_block(X, f=3, filters=[64, 64, 256], stage=2, block='a', strides=(1,1))
    X = identity_block(X, 3, [64, 64, 256], stage=2, block='b')
    X = identity_block(X, 3, [64, 64, 256], stage=2, block='c')
```

```
X = convolutional_block(X, f=3, filters=[128, 128, 512], stage=3, block='a', strides=(2,2))
X = identity_block(X, 3, [128, 128, 512], stage=3, block='b')
X = identity_block(X, 3, [128, 128, 512], stage=3, block='c')
X = identity_block(X, 3, [128, 128, 512], stage=3, block='d')

X = convolutional_block(X, f=3, filters=[256, 256, 1024], stage=4, block='a', strides=(2,2))
X = identity_block(X, 3, [256, 256, 1024], stage=4, block='b')
X = identity_block(X, 3, [256, 256, 1024], stage=4, block='c')
X = identity_block(X, 3, [256, 256, 1024], stage=4, block='d')
X = identity_block(X, 3, [256, 256, 1024], stage=4, block='e')
X = identity_block(X, 3, [256, 256, 1024], stage=4, block='f')

X = convolutional_block(X, f=3, filters=[512, 512, 2048], stage=5, block='a', strides=(2,2))
X = identity_block(X, 3, [512, 512, 2048], stage=5, block='b')
X = identity_block(X, 3, [512, 512, 2048], stage=5, block='c')
X = AveragePooling2D(pool_size=(2, 2), padding='same')(X)
X = Dropout(0.4)(X)

# Define fully connected layers and output
X = Flatten()(X)
X = Dense(units=512,activation="relu")(X)
X = Dense(units=256,activation="relu")(X)
X = Dense(units=3, activation="softmax")(X)

model = Model(inputs=input_layer, outputs=X, name='ResNet50')
model.summary()

opt = Adam(learning_rate=LEARNING_RATE)
model.compile(loss = keras.losses.categorical_crossentropy, optimizer=opt, metrics=['accuracy'])
```

```
    return model


def plot_curves(history):
    """
    Plots loss and accuracy and loss plots for
    training and validation datasets
    Arguments:
        history -- training history
    Returns: None
    """

    plt.plot(history.history['loss'], color='b', label="Training loss")
    plt.plot(history.history['val_loss'], color='r', label="Validation loss")
    plt.legend()
    plt.title('Training Loss VS Validation Loss')
    plt.show()

    plt.plot(history.history['accuracy'], color='b', label="Training accuracy")
    plt.plot(history.history['val_accuracy'], color='r',label="Validation accuracy")
    plt.title('Training Accuracy VS Validation Accuracy')
    plt.legend()
    plt.show()


def get_confusion_matrix(model, data_generator):
    """
    Calculates the accuracy and displays the
    confusion matrix for the input data
    Arguments:
        model           -- trained model
```

```
        data_generator  -- input data generator
    Returns: None
    """

    predictions = model.predict(data_generator, BATCH_SIZE)
    y_pred = np.argmax(predictions, axis=1)
    y_true = data_generator.classes
    class_names = ['COVID', 'Normal', 'Pneumonia']

    print("Score =", model.evaluate(data_generator, batch_size=BATCH_SIZE))
    print("Accuracy  = ", metrics.accuracy_score(y_true, y_pred))
    cm = metrics.confusion_matrix(y_true, y_pred)
    metrics.ConfusionMatrixDisplay(cm, display_labels=class_names).plot(cmap=plt.cm.Blues,
                                                                        xticks_rotation='vertical')
    plt.show()


def train_model(train_generator, val_generator):
    """
    Trains ResNet-50 model and saves the
    trained weights to an H5 file.
    Arguments:
        train_generator   -- train data generator
        val_generator     -- validation data generator
    Returns: Trained model
    """

    # Loads the model
    model = load_model()
    earlystop = keras.callbacks.EarlyStopping(monitor='val_accuracy', mode='max', verbose=1, patience=10)
    callbacks = [earlystop]
```

```
    history = model.fit(
        train_generator,
        batch_size=BATCH_SIZE,
        epochs=EPOCHS,
        validation_data=val_generator,
        validation_steps=val_generator.samples//BATCH_SIZE,
        steps_per_epoch=train_generator.samples//BATCH_SIZE,
        callbacks=callbacks)

    plot_curves(history)
    model.save_weights("model_resnet50.h5")
    print("Model saved successfully!")

    return model
```

In [2]:

```
train_generator, val_generator = load_data()
model = train_model(train_generator, val_generator)

print("Confusion matrix for train data:")
get_confusion_matrix(model, train_generator)

print("Confusion matrix for val/test data:")
get_confusion_matrix(model, val_generator)
```

```
Model: "ResNet50"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 224, 224, 3) 0
__________________________________________________________________________________________________
zero_padding2d (ZeroPadding2D)  (None, 230, 230, 3)  0           input_1[0][0]
__________________________________________________________________________________________________
conv1 (Conv2D)                  (None, 112, 112, 64) 9472        zero_padding2d[0][0]
__________________________________________________________________________________________________
bn_conv1 (BatchNormalization)   (None, 112, 112, 64) 256         conv1[0][0]
__________________________________________________________________________________________________
activation (Activation)         (None, 112, 112, 64) 0           bn_conv1[0][0]
__________________________________________________________________________________________________
max_pooling2d (MaxPooling2D)    (None, 55, 55, 64)   0           activation[0][0]
__________________________________________________________________________________________________
res2a_branch2a (Conv2D)         (None, 55, 55, 64)   4160        max_pooling2d[0][0]
__________________________________________________________________________________________________
bn2a_branch2a (BatchNormalizati (None, 55, 55, 64)   256         res2a_branch2a[0][0]
__________________________________________________________________________________________________
activation_1 (Activation)       (None, 55, 55, 64)   0           bn2a_branch2a[0][0]
__________________________________________________________________________________________________
res2a_branch2b (Conv2D)         (None, 55, 55, 64)   36928       activation_1[0][0]
__________________________________________________________________________________________________
bn2a_branch2b (BatchNormalizati (None, 55, 55, 64)   256         res2a_branch2b[0][0]
__________________________________________________________________________________________________
activation_2 (Activation)       (None, 55, 55, 64)   0           bn2a_branch2b[0][0]
__________________________________________________________________________________________________
res2a_branch2c (Conv2D)         (None, 55, 55, 256)  16640       activation_2[0][0]
__________________________________________________________________________________________________
```

```
res2a_branch1 (Conv2D)          (None, 55, 55, 256)  16640       max_pooling2d[0][0]
__________________________________________________________________________________________________
bn2a_branch2c (BatchNormalizati (None, 55, 55, 256)  1024        res2a_branch2c[0][0]
__________________________________________________________________________________________________
bn2a_branch1 (BatchNormalizatio (None, 55, 55, 256)  1024        res2a_branch1[0][0]
__________________________________________________________________________________________________
add (Add)                       (None, 55, 55, 256)  0           bn2a_branch2c[0][0]
                                                                 bn2a_branch1[0][0]
__________________________________________________________________________________________________
activation_3 (Activation)       (None, 55, 55, 256)  0           add[0][0]
__________________________________________________________________________________________________
res2b_branch2a (Conv2D)         (None, 55, 55, 64)   16448       activation_3[0][0]
__________________________________________________________________________________________________
bn2b_branch2a (BatchNormalizati (None, 55, 55, 64)   256         res2b_branch2a[0][0]
__________________________________________________________________________________________________
activation_4 (Activation)       (None, 55, 55, 64)   0           bn2b_branch2a[0][0]
__________________________________________________________________________________________________
res2b_branch2b (Conv2D)         (None, 55, 55, 64)   36928       activation_4[0][0]
__________________________________________________________________________________________________
bn2b_branch2b (BatchNormalizati (None, 55, 55, 64)   256         res2b_branch2b[0][0]
__________________________________________________________________________________________________
activation_5 (Activation)       (None, 55, 55, 64)   0           bn2b_branch2b[0][0]
__________________________________________________________________________________________________
res2b_branch2c (Conv2D)         (None, 55, 55, 256)  16640       activation_5[0][0]
__________________________________________________________________________________________________
bn2b_branch2c (BatchNormalizati (None, 55, 55, 256)  1024        res2b_branch2c[0][0]
__________________________________________________________________________________________________
add_1 (Add)                     (None, 55, 55, 256)  0           bn2b_branch2c[0][0]
                                                                 activation_3[0][0]
__________________________________________________________________________________________________
activation_6 (Activation)       (None, 55, 55, 256)  0           add_1[0][0]
```

```
__________________________________________________________________________________________________
res2c_branch2a (Conv2D)         (None, 55, 55, 64)   16448       activation_6[0][0]
__________________________________________________________________________________________________
bn2c_branch2a (BatchNormalizati (None, 55, 55, 64)   256         res2c_branch2a[0][0]
__________________________________________________________________________________________________
activation_7 (Activation)       (None, 55, 55, 64)   0           bn2c_branch2a[0][0]
__________________________________________________________________________________________________
res2c_branch2b (Conv2D)         (None, 55, 55, 64)   36928       activation_7[0][0]
__________________________________________________________________________________________________
bn2c_branch2b (BatchNormalizati (None, 55, 55, 64)   256         res2c_branch2b[0][0]
__________________________________________________________________________________________________
activation_8 (Activation)       (None, 55, 55, 64)   0           bn2c_branch2b[0][0]
__________________________________________________________________________________________________
res2c_branch2c (Conv2D)         (None, 55, 55, 256)  16640       activation_8[0][0]
__________________________________________________________________________________________________
bn2c_branch2c (BatchNormalizati (None, 55, 55, 256)  1024        res2c_branch2c[0][0]
__________________________________________________________________________________________________
add_2 (Add)                     (None, 55, 55, 256)  0           bn2c_branch2c[0][0]
                                                                 activation_6[0][0]
__________________________________________________________________________________________________
activation_9 (Activation)       (None, 55, 55, 256)  0           add_2[0][0]
__________________________________________________________________________________________________
res3a_branch2a (Conv2D)         (None, 28, 28, 128)  32896       activation_9[0][0]
__________________________________________________________________________________________________
bn3a_branch2a (BatchNormalizati (None, 28, 28, 128)  512         res3a_branch2a[0][0]
__________________________________________________________________________________________________
activation_10 (Activation)      (None, 28, 28, 128)  0           bn3a_branch2a[0][0]
__________________________________________________________________________________________________
res3a_branch2b (Conv2D)         (None, 28, 28, 128)  147584      activation_10[0][0]
__________________________________________________________________________________________________
bn3a_branch2b (BatchNormalizati (None, 28, 28, 128)  512         res3a_branch2b[0][0]
```

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__________________________________________________________________________________________________
activation_11 (Activation)      (None, 28, 28, 128)  0           bn3a_branch2b[0][0]
__________________________________________________________________________________________________
res3a_branch2c (Conv2D)         (None, 28, 28, 512)  66048       activation_11[0][0]
__________________________________________________________________________________________________
res3a_branch1 (Conv2D)          (None, 28, 28, 512)  131584      activation_9[0][0]
__________________________________________________________________________________________________
bn3a_branch2c (BatchNormalizati (None, 28, 28, 512)  2048        res3a_branch2c[0][0]
__________________________________________________________________________________________________
bn3a_branch1 (BatchNormalizatio (None, 28, 28, 512)  2048        res3a_branch1[0][0]
__________________________________________________________________________________________________
add_3 (Add)                     (None, 28, 28, 512)  0           bn3a_branch2c[0][0]
                                                                 bn3a_branch1[0][0]
__________________________________________________________________________________________________
activation_12 (Activation)      (None, 28, 28, 512)  0           add_3[0][0]
__________________________________________________________________________________________________
res3b_branch2a (Conv2D)         (None, 28, 28, 128)  65664       activation_12[0][0]
__________________________________________________________________________________________________
bn3b_branch2a (BatchNormalizati (None, 28, 28, 128)  512         res3b_branch2a[0][0]
__________________________________________________________________________________________________
activation_13 (Activation)      (None, 28, 28, 128)  0           bn3b_branch2a[0][0]
__________________________________________________________________________________________________
res3b_branch2b (Conv2D)         (None, 28, 28, 128)  147584      activation_13[0][0]
__________________________________________________________________________________________________
bn3b_branch2b (BatchNormalizati (None, 28, 28, 128)  512         res3b_branch2b[0][0]
__________________________________________________________________________________________________
activation_14 (Activation)      (None, 28, 28, 128)  0           bn3b_branch2b[0][0]
__________________________________________________________________________________________________
res3b_branch2c (Conv2D)         (None, 28, 28, 512)  66048       activation_14[0][0]
__________________________________________________________________________________________________
bn3b_branch2c (BatchNormalizati (None, 28, 28, 512)  2048        res3b_branch2c[0][0]
```

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__________________________________________________________________________________________________
add_4 (Add)                     (None, 28, 28, 512)  0           bn3b_branch2c[0][0]
                                                                 activation_12[0][0]
__________________________________________________________________________________________________
activation_15 (Activation)      (None, 28, 28, 512)  0           add_4[0][0]
__________________________________________________________________________________________________
res3c_branch2a (Conv2D)         (None, 28, 28, 128)  65664       activation_15[0][0]
__________________________________________________________________________________________________
bn3c_branch2a (BatchNormalizati (None, 28, 28, 128)  512         res3c_branch2a[0][0]
__________________________________________________________________________________________________
activation_16 (Activation)      (None, 28, 28, 128)  0           bn3c_branch2a[0][0]
__________________________________________________________________________________________________
res3c_branch2b (Conv2D)         (None, 28, 28, 128)  147584      activation_16[0][0]
__________________________________________________________________________________________________
bn3c_branch2b (BatchNormalizati (None, 28, 28, 128)  512         res3c_branch2b[0][0]
__________________________________________________________________________________________________
activation_17 (Activation)      (None, 28, 28, 128)  0           bn3c_branch2b[0][0]
__________________________________________________________________________________________________
res3c_branch2c (Conv2D)         (None, 28, 28, 512)  66048       activation_17[0][0]
__________________________________________________________________________________________________
bn3c_branch2c (BatchNormalizati (None, 28, 28, 512)  2048        res3c_branch2c[0][0]
__________________________________________________________________________________________________
add_5 (Add)                     (None, 28, 28, 512)  0           bn3c_branch2c[0][0]
                                                                 activation_15[0][0]
__________________________________________________________________________________________________
activation_18 (Activation)      (None, 28, 28, 512)  0           add_5[0][0]
__________________________________________________________________________________________________
res3d_branch2a (Conv2D)         (None, 28, 28, 128)  65664       activation_18[0][0]
__________________________________________________________________________________________________
bn3d_branch2a (BatchNormalizati (None, 28, 28, 128)  512         res3d_branch2a[0][0]
__________________________________________________________________________________________________
```

```
activation_19 (Activation)      (None, 28, 28, 128)  0          bn3d_branch2a[0][0]
__________________________________________________________________________________________________
res3d_branch2b (Conv2D)         (None, 28, 28, 128)  147584     activation_19[0][0]
__________________________________________________________________________________________________
bn3d_branch2b (BatchNormalizati (None, 28, 28, 128)  512        res3d_branch2b[0][0]
__________________________________________________________________________________________________
activation_20 (Activation)      (None, 28, 28, 128)  0          bn3d_branch2b[0][0]
__________________________________________________________________________________________________
res3d_branch2c (Conv2D)         (None, 28, 28, 512)  66048      activation_20[0][0]
__________________________________________________________________________________________________
bn3d_branch2c (BatchNormalizati (None, 28, 28, 512)  2048       res3d_branch2c[0][0]
__________________________________________________________________________________________________
add_6 (Add)                     (None, 28, 28, 512)  0          bn3d_branch2c[0][0]
                                                                activation_18[0][0]
__________________________________________________________________________________________________
activation_21 (Activation)      (None, 28, 28, 512)  0          add_6[0][0]
__________________________________________________________________________________________________
res4a_branch2a (Conv2D)         (None, 14, 14, 256)  131328     activation_21[0][0]
__________________________________________________________________________________________________
bn4a_branch2a (BatchNormalizati (None, 14, 14, 256)  1024       res4a_branch2a[0][0]
__________________________________________________________________________________________________
activation_22 (Activation)      (None, 14, 14, 256)  0          bn4a_branch2a[0][0]
__________________________________________________________________________________________________
res4a_branch2b (Conv2D)         (None, 14, 14, 256)  590080     activation_22[0][0]
__________________________________________________________________________________________________
bn4a_branch2b (BatchNormalizati (None, 14, 14, 256)  1024       res4a_branch2b[0][0]
__________________________________________________________________________________________________
activation_23 (Activation)      (None, 14, 14, 256)  0          bn4a_branch2b[0][0]
__________________________________________________________________________________________________
res4a_branch2c (Conv2D)         (None, 14, 14, 1024) 263168     activation_23[0][0]
__________________________________________________________________________________________________
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res4a_branch1 (Conv2D)          (None, 14, 14, 1024) 525312      activation_21[0][0]
__________________________________________________________________________________________________
bn4a_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096        res4a_branch2c[0][0]
__________________________________________________________________________________________________
bn4a_branch1 (BatchNormalizatio (None, 14, 14, 1024) 4096        res4a_branch1[0][0]
__________________________________________________________________________________________________
add_7 (Add)                     (None, 14, 14, 1024) 0           bn4a_branch2c[0][0]
                                                                 bn4a_branch1[0][0]
__________________________________________________________________________________________________
activation_24 (Activation)      (None, 14, 14, 1024) 0           add_7[0][0]
__________________________________________________________________________________________________
res4b_branch2a (Conv2D)         (None, 14, 14, 256)  262400      activation_24[0][0]
__________________________________________________________________________________________________
bn4b_branch2a (BatchNormalizati (None, 14, 14, 256)  1024        res4b_branch2a[0][0]
__________________________________________________________________________________________________
activation_25 (Activation)      (None, 14, 14, 256)  0           bn4b_branch2a[0][0]
__________________________________________________________________________________________________
res4b_branch2b (Conv2D)         (None, 14, 14, 256)  590080      activation_25[0][0]
__________________________________________________________________________________________________
bn4b_branch2b (BatchNormalizati (None, 14, 14, 256)  1024        res4b_branch2b[0][0]
__________________________________________________________________________________________________
activation_26 (Activation)      (None, 14, 14, 256)  0           bn4b_branch2b[0][0]
__________________________________________________________________________________________________
res4b_branch2c (Conv2D)         (None, 14, 14, 1024) 263168      activation_26[0][0]
__________________________________________________________________________________________________
bn4b_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096        res4b_branch2c[0][0]
__________________________________________________________________________________________________
add_8 (Add)                     (None, 14, 14, 1024) 0           bn4b_branch2c[0][0]
                                                                 activation_24[0][0]
__________________________________________________________________________________________________
activation_27 (Activation)      (None, 14, 14, 1024) 0           add_8[0][0]
```

```
____________________________________________________________________________________________________
res4c_branch2a (Conv2D)         (None, 14, 14, 256)  262400      activation_27[0][0]
____________________________________________________________________________________________________
bn4c_branch2a (BatchNormalizati (None, 14, 14, 256)  1024        res4c_branch2a[0][0]
____________________________________________________________________________________________________
activation_28 (Activation)      (None, 14, 14, 256)  0           bn4c_branch2a[0][0]
____________________________________________________________________________________________________
res4c_branch2b (Conv2D)         (None, 14, 14, 256)  590080      activation_28[0][0]
____________________________________________________________________________________________________
bn4c_branch2b (BatchNormalizati (None, 14, 14, 256)  1024        res4c_branch2b[0][0]
____________________________________________________________________________________________________
activation_29 (Activation)      (None, 14, 14, 256)  0           bn4c_branch2b[0][0]
____________________________________________________________________________________________________
res4c_branch2c (Conv2D)         (None, 14, 14, 1024) 263168      activation_29[0][0]
____________________________________________________________________________________________________
bn4c_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096        res4c_branch2c[0][0]
____________________________________________________________________________________________________
add_9 (Add)                     (None, 14, 14, 1024) 0           bn4c_branch2c[0][0]
                                                                 activation_27[0][0]
____________________________________________________________________________________________________
activation_30 (Activation)      (None, 14, 14, 1024) 0           add_9[0][0]
____________________________________________________________________________________________________
res4d_branch2a (Conv2D)         (None, 14, 14, 256)  262400      activation_30[0][0]
____________________________________________________________________________________________________
bn4d_branch2a (BatchNormalizati (None, 14, 14, 256)  1024        res4d_branch2a[0][0]
____________________________________________________________________________________________________
activation_31 (Activation)      (None, 14, 14, 256)  0           bn4d_branch2a[0][0]
____________________________________________________________________________________________________
res4d_branch2b (Conv2D)         (None, 14, 14, 256)  590080      activation_31[0][0]
____________________________________________________________________________________________________
bn4d_branch2b (BatchNormalizati (None, 14, 14, 256)  1024        res4d_branch2b[0][0]
```

```
__________________________________________________________________________________________________
activation_32 (Activation)      (None, 14, 14, 256)  0           bn4d_branch2b[0][0]
__________________________________________________________________________________________________
res4d_branch2c (Conv2D)         (None, 14, 14, 1024) 263168      activation_32[0][0]
__________________________________________________________________________________________________
bn4d_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096        res4d_branch2c[0][0]
__________________________________________________________________________________________________
add_10 (Add)                    (None, 14, 14, 1024) 0           bn4d_branch2c[0][0]
                                                                 activation_30[0][0]
__________________________________________________________________________________________________
activation_33 (Activation)      (None, 14, 14, 1024) 0           add_10[0][0]
__________________________________________________________________________________________________
res4e_branch2a (Conv2D)         (None, 14, 14, 256)  262400      activation_33[0][0]
__________________________________________________________________________________________________
bn4e_branch2a (BatchNormalizati (None, 14, 14, 256)  1024        res4e_branch2a[0][0]
__________________________________________________________________________________________________
activation_34 (Activation)      (None, 14, 14, 256)  0           bn4e_branch2a[0][0]
__________________________________________________________________________________________________
res4e_branch2b (Conv2D)         (None, 14, 14, 256)  590080      activation_34[0][0]
__________________________________________________________________________________________________
bn4e_branch2b (BatchNormalizati (None, 14, 14, 256)  1024        res4e_branch2b[0][0]
__________________________________________________________________________________________________
activation_35 (Activation)      (None, 14, 14, 256)  0           bn4e_branch2b[0][0]
__________________________________________________________________________________________________
res4e_branch2c (Conv2D)         (None, 14, 14, 1024) 263168      activation_35[0][0]
__________________________________________________________________________________________________
bn4e_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096        res4e_branch2c[0][0]
__________________________________________________________________________________________________
add_11 (Add)                    (None, 14, 14, 1024) 0           bn4e_branch2c[0][0]
                                                                 activation_33[0][0]
__________________________________________________________________________________________________
```

```
activation_36 (Activation)      (None, 14, 14, 1024) 0          add_11[0][0]
__________________________________________________________________________________________________
res4f_branch2a (Conv2D)         (None, 14, 14, 256)  262400     activation_36[0][0]
__________________________________________________________________________________________________
bn4f_branch2a (BatchNormalizati (None, 14, 14, 256)  1024       res4f_branch2a[0][0]
__________________________________________________________________________________________________
activation_37 (Activation)      (None, 14, 14, 256)  0          bn4f_branch2a[0][0]
__________________________________________________________________________________________________
res4f_branch2b (Conv2D)         (None, 14, 14, 256)  590080     activation_37[0][0]
__________________________________________________________________________________________________
bn4f_branch2b (BatchNormalizati (None, 14, 14, 256)  1024       res4f_branch2b[0][0]
__________________________________________________________________________________________________
activation_38 (Activation)      (None, 14, 14, 256)  0          bn4f_branch2b[0][0]
__________________________________________________________________________________________________
res4f_branch2c (Conv2D)         (None, 14, 14, 1024) 263168     activation_38[0][0]
__________________________________________________________________________________________________
bn4f_branch2c (BatchNormalizati (None, 14, 14, 1024) 4096       res4f_branch2c[0][0]
__________________________________________________________________________________________________
add_12 (Add)                    (None, 14, 14, 1024) 0          bn4f_branch2c[0][0]
                                                                activation_36[0][0]
__________________________________________________________________________________________________
activation_39 (Activation)      (None, 14, 14, 1024) 0          add_12[0][0]
__________________________________________________________________________________________________
res5a_branch2a (Conv2D)         (None, 7, 7, 512)    524800     activation_39[0][0]
__________________________________________________________________________________________________
bn5a_branch2a (BatchNormalizati (None, 7, 7, 512)    2048       res5a_branch2a[0][0]
__________________________________________________________________________________________________
activation_40 (Activation)      (None, 7, 7, 512)    0          bn5a_branch2a[0][0]
__________________________________________________________________________________________________
res5a_branch2b (Conv2D)         (None, 7, 7, 512)    2359808    activation_40[0][0]
__________________________________________________________________________________________________
```

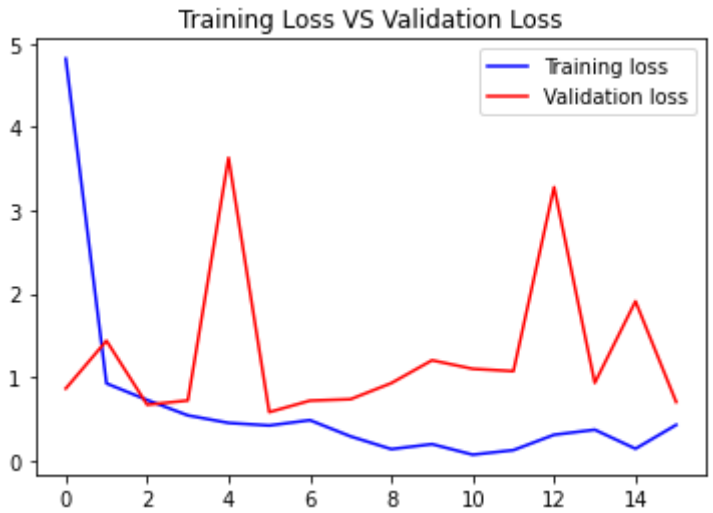
```
bn5a_branch2b (BatchNormalizati (None, 7, 7, 512)    2048        res5a_branch2b[0][0]
__________________________________________________________________________________________
activation_41 (Activation)      (None, 7, 7, 512)    0           bn5a_branch2b[0][0]
__________________________________________________________________________________________
res5a_branch2c (Conv2D)         (None, 7, 7, 2048)   1050624     activation_41[0][0]
__________________________________________________________________________________________
res5a_branch1 (Conv2D)          (None, 7, 7, 2048)   2099200     activation_39[0][0]
__________________________________________________________________________________________
bn5a_branch2c (BatchNormalizati (None, 7, 7, 2048)   8192        res5a_branch2c[0][0]
__________________________________________________________________________________________
bn5a_branch1 (BatchNormalizatio (None, 7, 7, 2048)   8192        res5a_branch1[0][0]
__________________________________________________________________________________________
add_13 (Add)                    (None, 7, 7, 2048)   0           bn5a_branch2c[0][0]
                                                                 bn5a_branch1[0][0]
__________________________________________________________________________________________
activation_42 (Activation)      (None, 7, 7, 2048)   0           add_13[0][0]
__________________________________________________________________________________________
res5b_branch2a (Conv2D)         (None, 7, 7, 512)    1049088     activation_42[0][0]
__________________________________________________________________________________________
bn5b_branch2a (BatchNormalizati (None, 7, 7, 512)    2048        res5b_branch2a[0][0]
__________________________________________________________________________________________
activation_43 (Activation)      (None, 7, 7, 512)    0           bn5b_branch2a[0][0]
__________________________________________________________________________________________
res5b_branch2b (Conv2D)         (None, 7, 7, 512)    2359808     activation_43[0][0]
__________________________________________________________________________________________
bn5b_branch2b (BatchNormalizati (None, 7, 7, 512)    2048        res5b_branch2b[0][0]
__________________________________________________________________________________________
activation_44 (Activation)      (None, 7, 7, 512)    0           bn5b_branch2b[0][0]
__________________________________________________________________________________________
res5b_branch2c (Conv2D)         (None, 7, 7, 2048)   1050624     activation_44[0][0]
__________________________________________________________________________________________
```

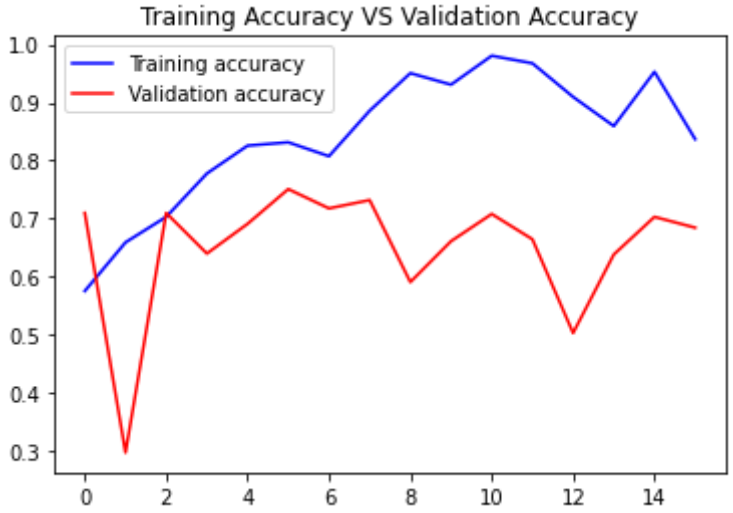
```
bn5b_branch2c (BatchNormalizati (None, 7, 7, 2048)   8192        res5b_branch2c[0][0]
__________________________________________________________________________________________
add_14 (Add)                    (None, 7, 7, 2048)   0           bn5b_branch2c[0][0]
                                                                 activation_42[0][0]
__________________________________________________________________________________________
activation_45 (Activation)      (None, 7, 7, 2048)   0           add_14[0][0]
__________________________________________________________________________________________
res5c_branch2a (Conv2D)         (None, 7, 7, 512)    1049088     activation_45[0][0]
__________________________________________________________________________________________
bn5c_branch2a (BatchNormalizati (None, 7, 7, 512)    2048        res5c_branch2a[0][0]
__________________________________________________________________________________________
activation_46 (Activation)      (None, 7, 7, 512)    0           bn5c_branch2a[0][0]
__________________________________________________________________________________________
res5c_branch2b (Conv2D)         (None, 7, 7, 512)    2359808     activation_46[0][0]
__________________________________________________________________________________________
bn5c_branch2b (BatchNormalizati (None, 7, 7, 512)    2048        res5c_branch2b[0][0]
__________________________________________________________________________________________
activation_47 (Activation)      (None, 7, 7, 512)    0           bn5c_branch2b[0][0]
__________________________________________________________________________________________
res5c_branch2c (Conv2D)         (None, 7, 7, 2048)   1050624     activation_47[0][0]
__________________________________________________________________________________________
bn5c_branch2c (BatchNormalizati (None, 7, 7, 2048)   8192        res5c_branch2c[0][0]
__________________________________________________________________________________________
add_15 (Add)                    (None, 7, 7, 2048)   0           bn5c_branch2c[0][0]
                                                                 activation_45[0][0]
__________________________________________________________________________________________
activation_48 (Activation)      (None, 7, 7, 2048)   0           add_15[0][0]
__________________________________________________________________________________________
average_pooling2d (AveragePooli (None, 4, 4, 2048)   0           activation_48[0][0]
__________________________________________________________________________________________
dropout (Dropout)               (None, 4, 4, 2048)   0           average_pooling2d[0][0]
```

```
__________________________________________________________________________________________________
flatten (Flatten)               (None, 32768)        0           dropout[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 512)          16777728    flatten[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 256)          131328      dense[0][0]
__________________________________________________________________________________________________
dense_2 (Dense)                 (None, 3)            771         dense_1[0][0]
==================================================================================================
Total params: 40,497,539
Trainable params: 40,444,419
Non-trainable params: 53,120
__________________________________________________________________________________________________


2021-10-20 17:36:31.922874: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the ML
IR Optimization Passes are enabled (registered 2)


Epoch 1/100


2021-10-20 17:36:40.160462: I tensorflow/stream_executor/cuda/cuda_dnn.cc:369] Loaded cuDNN version 8005
```

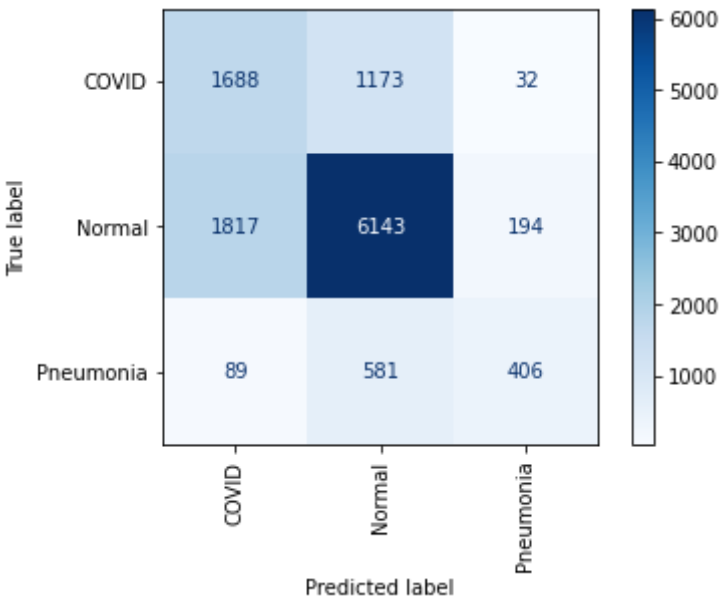
```
189/189 [==============================] - 262s 1s/step - loss: 4.8214 - accuracy: 0.5751 - val_loss: 0.86
12 - val_accuracy: 0.7094
Epoch 2/100
189/189 [==============================] - 82s 430ms/step - loss: 0.9222 - accuracy: 0.6588 - val_loss: 1.
4347 - val_accuracy: 0.2965
Epoch 3/100
189/189 [==============================] - 82s 433ms/step - loss: 0.7233 - accuracy: 0.7029 - val_loss: 0.
6663 - val_accuracy: 0.7094
Epoch 4/100
189/189 [==============================] - 83s 440ms/step - loss: 0.5386 - accuracy: 0.7776 - val_loss: 0.
7174 - val_accuracy: 0.6396
Epoch 5/100
189/189 [==============================] - 85s 449ms/step - loss: 0.4483 - accuracy: 0.8256 - val_loss: 3.
6309 - val_accuracy: 0.6908
Epoch 6/100
189/189 [==============================] - 87s 457ms/step - loss: 0.4173 - accuracy: 0.8313 - val_loss: 0.
5777 - val_accuracy: 0.7507
Epoch 7/100
189/189 [==============================] - 83s 440ms/step - loss: 0.4813 - accuracy: 0.8074 - val_loss: 0.
7154 - val_accuracy: 0.7174
Epoch 8/100
189/189 [==============================] - 85s 449ms/step - loss: 0.2863 - accuracy: 0.8858 - val_loss: 0.
7330 - val_accuracy: 0.7317
Epoch 9/100
189/189 [==============================] - 93s 491ms/step - loss: 0.1337 - accuracy: 0.9506 - val_loss: 0.
9259 - val_accuracy: 0.5904
Epoch 10/100
189/189 [==============================] - 83s 438ms/step - loss: 0.1934 - accuracy: 0.9308 - val_loss: 1.
2001 - val_accuracy: 0.6609
Epoch 11/100
```

```
189/189 [==============================] - 81s 427ms/step - loss: 0.0668 - accuracy: 0.9806 - val_loss: 1.
0974 - val_accuracy: 0.7078
Epoch 12/100
189/189 [==============================] - 83s 439ms/step - loss: 0.1214 - accuracy: 0.9676 - val_loss: 1.
0696 - val_accuracy: 0.6642
Epoch 13/100
189/189 [==============================] - 82s 434ms/step - loss: 0.3060 - accuracy: 0.9096 - val_loss: 3.
2787 - val_accuracy: 0.5027
Epoch 14/100
189/189 [==============================] - 83s 439ms/step - loss: 0.3663 - accuracy: 0.8594 - val_loss: 0.
9287 - val_accuracy: 0.6380
Epoch 15/100
189/189 [==============================] - 84s 444ms/step - loss: 0.1385 - accuracy: 0.9529 - val_loss: 1.
9083 - val_accuracy: 0.7028
Epoch 16/100
189/189 [==============================] - 85s 448ms/step - loss: 0.4247 - accuracy: 0.8367 - val_loss: 0.
6992 - val_accuracy: 0.6842
Epoch 00016: early stopping
```

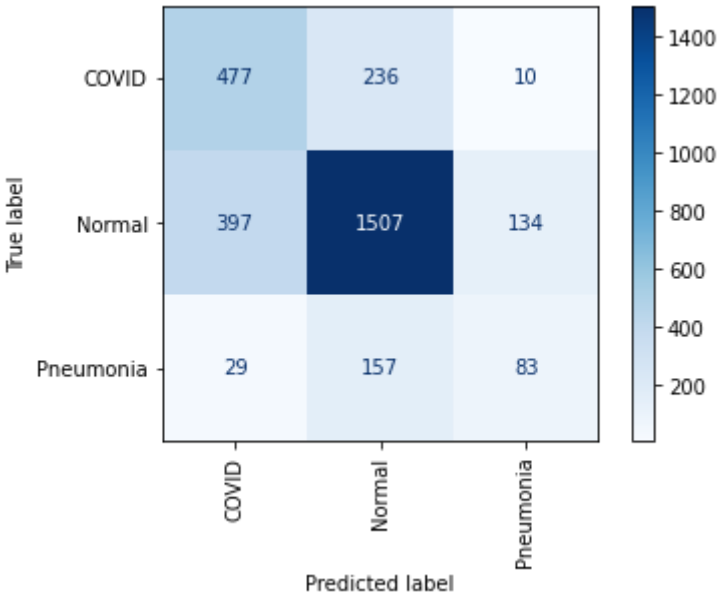

Training Loss VS Validation Loss
Training loss
Validation loss
5
4
3
2
1
0
0
2
4
6
8
10
12
14


Training Accuracy VS Validation Accuracy
Training accuracy
Validation accuracy
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
2
4
6
8
10
12
14

```
Model saved successfully!
Confusion matrix for train data:
190/190 [==============================] - 59s 312ms/step - loss: 0.6621 - accuracy: 0.6795
Score = [0.6620919108390808, 0.6794523000717163]
Accuracy  =  0.6794522807885837
```




```
Confusion matrix for val/test data:
48/48 [==============================] - 15s 305ms/step - loss: 0.7040 - accuracy: 0.6822
Score = [0.7039801478385925, 0.6821781992912292]
Accuracy  =  0.6821782178217822
```


COVID
Normal
Pneumonia
True label
477
236
10
397
1507
134
29
157
83
COVID
Normal
Pneumonia
Predicted label
1400
1200
1000
800
600
400
200