In [1]:

```
"""
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"""

import numpy as np
from tensorflow import keras
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.applications import ResNet50
from tensorflow.keras.models import Model
from tensorflow.keras.layers import (
    Dense, Input, GlobalAveragePooling2D)
from tensorflow.keras.applications.resnet50 import preprocess_input

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

TRAIN_PATH = "../input/covid19/"
EPOCHS = 50
BATCH_SIZE = 128
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 load_model():
    """
    Creates a keras ResNet-50 model
    Arguments: None
    Returns: ResNet-50 Model
    """

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

```
    # Load ResNet50 model from keras using imagenet weights for transfer learning
    base_model = ResNet50(include_top=False, weights='imagenet', input_tensor=input_layer)

    for layer in base_model.layers:
        layer.trainable = False

    x = base_model.output
    x = GlobalAveragePooling2D()(x)
    x = Dense(128, activation='relu')(x)
    x = Dense(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=5)
    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)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50_weights
_tf_dim_ordering_tf_kernels_notop.h5
94773248/94765736 [==============================] - 0s 0us/step
94781440/94765736 [==============================] - 0s 0us/step
Model: "ResNet50"
__________________________________________________________________________________________________
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]
__________________________________________________________________________________________________
conv1_bn (BatchNormalization)   (None, 112, 112, 64) 256         conv1_conv[0][0]
__________________________________________________________________________________________________
conv1_relu (Activation)         (None, 112, 112, 64) 0           conv1_bn[0][0]
__________________________________________________________________________________________________
pool1_pad (ZeroPadding2D)       (None, 114, 114, 64) 0           conv1_relu[0][0]
__________________________________________________________________________________________________
pool1_pool (MaxPooling2D)       (None, 56, 56, 64)   0           pool1_pad[0][0]
__________________________________________________________________________________________________
conv2_block1_1_conv (Conv2D)    (None, 56, 56, 64)   4160        pool1_pool[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_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block1_1_relu[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       pool1_pool[0][0]
__________________________________________________________________________________________________
conv2_block1_3_conv (Conv2D)    (None, 56, 56, 256)  16640       conv2_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv2_block1_0_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv2_block1_add (Add)          (None, 56, 56, 256)  0           conv2_block1_0_bn[0][0]
                                                                 conv2_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv2_block1_out (Activation)   (None, 56, 56, 256)  0           conv2_block1_add[0][0]
__________________________________________________________________________________________________
conv2_block2_1_conv (Conv2D)    (None, 56, 56, 64)   16448       conv2_block1_out[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_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block2_1_relu[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_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block2_3_conv[0][0]
__________________________________________________________________________________________
conv2_block2_add (Add)          (None, 56, 56, 256)  0           conv2_block1_out[0][0]
                                                                 conv2_block2_3_bn[0][0]
__________________________________________________________________________________________
conv2_block2_out (Activation)   (None, 56, 56, 256)  0           conv2_block2_add[0][0]
__________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, 56, 56, 64)   16448       conv2_block2_out[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_conv (Conv2D)    (None, 56, 56, 64)   36928       conv2_block3_1_relu[0][0]
__________________________________________________________________________________________
conv2_block3_2_bn (BatchNormali (None, 56, 56, 64)   256         conv2_block3_2_conv[0][0]
__________________________________________________________________________________________
conv2_block3_2_relu (Activation (None, 56, 56, 64)   0           conv2_block3_2_bn[0][0]
__________________________________________________________________________________________
conv2_block3_3_conv (Conv2D)    (None, 56, 56, 256)  16640       conv2_block3_2_relu[0][0]
__________________________________________________________________________________________
conv2_block3_3_bn (BatchNormali (None, 56, 56, 256)  1024        conv2_block3_3_conv[0][0]
__________________________________________________________________________________________
conv2_block3_add (Add)          (None, 56, 56, 256)  0           conv2_block2_out[0][0]
                                                                 conv2_block3_3_bn[0][0]
__________________________________________________________________________________________
conv2_block3_out (Activation)   (None, 56, 56, 256)  0           conv2_block3_add[0][0]
__________________________________________________________________________________________
conv3_block1_1_conv (Conv2D)    (None, 28, 28, 128)  32896       conv2_block3_out[0][0]
__________________________________________________________________________________________
conv3_block1_1_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block1_1_conv[0][0]
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__________________________________________________________________________________________________
conv3_block1_1_relu (Activation (None, 28, 28, 128)  0           conv3_block1_1_bn[0][0]
__________________________________________________________________________________________________
conv3_block1_2_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block1_1_relu[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      conv2_block3_out[0][0]
__________________________________________________________________________________________________
conv3_block1_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv3_block1_0_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv3_block1_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv3_block1_add (Add)          (None, 28, 28, 512)  0           conv3_block1_0_bn[0][0]
                                                                 conv3_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv3_block1_out (Activation)   (None, 28, 28, 512)  0           conv3_block1_add[0][0]
__________________________________________________________________________________________________
conv3_block2_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block1_out[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_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv3_block2_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block2_2_conv[0][0]
```

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__________________________________________________________________________________________________
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_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv3_block2_add (Add)          (None, 28, 28, 512)  0           conv3_block1_out[0][0]
                                                                 conv3_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv3_block2_out (Activation)   (None, 28, 28, 512)  0           conv3_block2_add[0][0]
__________________________________________________________________________________________________
conv3_block3_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block2_out[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_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block3_1_relu[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_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv3_block3_add (Add)          (None, 28, 28, 512)  0           conv3_block2_out[0][0]
                                                                 conv3_block3_3_bn[0][0]
__________________________________________________________________________________________________
```

```
conv3_block3_out (Activation)   (None, 28, 28, 512)  0           conv3_block3_add[0][0]
__________________________________________________________________________________________
conv3_block4_1_conv (Conv2D)    (None, 28, 28, 128)  65664       conv3_block3_out[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_conv (Conv2D)    (None, 28, 28, 128)  147584      conv3_block4_1_relu[0][0]
__________________________________________________________________________________________
conv3_block4_2_bn (BatchNormali (None, 28, 28, 128)  512         conv3_block4_2_conv[0][0]
__________________________________________________________________________________________
conv3_block4_2_relu (Activation (None, 28, 28, 128)  0           conv3_block4_2_bn[0][0]
__________________________________________________________________________________________
conv3_block4_3_conv (Conv2D)    (None, 28, 28, 512)  66048       conv3_block4_2_relu[0][0]
__________________________________________________________________________________________
conv3_block4_3_bn (BatchNormali (None, 28, 28, 512)  2048        conv3_block4_3_conv[0][0]
__________________________________________________________________________________________
conv3_block4_add (Add)          (None, 28, 28, 512)  0           conv3_block3_out[0][0]
                                                                 conv3_block4_3_bn[0][0]
__________________________________________________________________________________________
conv3_block4_out (Activation)   (None, 28, 28, 512)  0           conv3_block4_add[0][0]
__________________________________________________________________________________________
conv4_block1_1_conv (Conv2D)    (None, 14, 14, 256)  131328      conv3_block4_out[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_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block1_1_relu[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      conv3_block4_out[0][0]
__________________________________________________________________________________________________
conv4_block1_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block1_0_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv4_block1_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block1_add (Add)          (None, 14, 14, 1024) 0           conv4_block1_0_bn[0][0]
                                                                 conv4_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block1_out (Activation)   (None, 14, 14, 1024) 0           conv4_block1_add[0][0]
__________________________________________________________________________________________________
conv4_block2_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block1_out[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_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block2_1_relu[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_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block2_add (Add)          (None, 14, 14, 1024) 0           conv4_block1_out[0][0]
                                                                 conv4_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block2_out (Activation)   (None, 14, 14, 1024) 0           conv4_block2_add[0][0]
__________________________________________________________________________________________________
conv4_block3_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block2_out[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_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block3_1_relu[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_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block3_add (Add)          (None, 14, 14, 1024) 0           conv4_block2_out[0][0]
                                                                 conv4_block3_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block3_out (Activation)   (None, 14, 14, 1024) 0           conv4_block3_add[0][0]
__________________________________________________________________________________________________
conv4_block4_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block3_out[0][0]
__________________________________________________________________________________________________
conv4_block4_1_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block4_1_conv[0][0]
```

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__________________________________________________________________________________________________
conv4_block4_1_relu (Activation (None, 14, 14, 256)  0           conv4_block4_1_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block4_1_relu[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_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block4_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block4_add (Add)          (None, 14, 14, 1024) 0           conv4_block3_out[0][0]
                                                                 conv4_block4_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block4_out (Activation)   (None, 14, 14, 1024) 0           conv4_block4_add[0][0]
__________________________________________________________________________________________________
conv4_block5_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block4_out[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_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block5_1_relu[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]
```

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__________________________________________________________________________________________________
conv4_block5_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block5_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block5_add (Add)          (None, 14, 14, 1024) 0           conv4_block4_out[0][0]
                                                                 conv4_block5_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block5_out (Activation)   (None, 14, 14, 1024) 0           conv4_block5_add[0][0]
__________________________________________________________________________________________________
conv4_block6_1_conv (Conv2D)    (None, 14, 14, 256)  262400      conv4_block5_out[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]
__________________________________________________________________________________________________
conv4_block6_2_conv (Conv2D)    (None, 14, 14, 256)  590080      conv4_block6_1_relu[0][0]
__________________________________________________________________________________________________
conv4_block6_2_bn (BatchNormali (None, 14, 14, 256)  1024        conv4_block6_2_conv[0][0]
__________________________________________________________________________________________________
conv4_block6_2_relu (Activation (None, 14, 14, 256)  0           conv4_block6_2_bn[0][0]
__________________________________________________________________________________________________
conv4_block6_3_conv (Conv2D)    (None, 14, 14, 1024) 263168      conv4_block6_2_relu[0][0]
__________________________________________________________________________________________________
conv4_block6_3_bn (BatchNormali (None, 14, 14, 1024) 4096        conv4_block6_3_conv[0][0]
__________________________________________________________________________________________________
conv4_block6_add (Add)          (None, 14, 14, 1024) 0           conv4_block5_out[0][0]
                                                                 conv4_block6_3_bn[0][0]
__________________________________________________________________________________________________
conv4_block6_out (Activation)   (None, 14, 14, 1024) 0           conv4_block6_add[0][0]
__________________________________________________________________________________________________
conv5_block1_1_conv (Conv2D)    (None, 7, 7, 512)    524800      conv4_block6_out[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]
__________________________________________________________________________________________________
conv5_block1_2_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block1_1_relu[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     conv4_block6_out[0][0]
__________________________________________________________________________________________________
conv5_block1_3_conv (Conv2D)    (None, 7, 7, 2048)   1050624     conv5_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_add (Add)          (None, 7, 7, 2048)   0           conv5_block1_0_bn[0][0]
                                                                 conv5_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_out (Activation)   (None, 7, 7, 2048)   0           conv5_block1_add[0][0]
__________________________________________________________________________________________________
conv5_block2_1_conv (Conv2D)    (None, 7, 7, 512)    1049088     conv5_block1_out[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           conv5_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block2_2_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block2_1_relu[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_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_add (Add)          (None, 7, 7, 2048)   0           conv5_block1_out[0][0]
                                                                 conv5_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv5_block2_out (Activation)   (None, 7, 7, 2048)   0           conv5_block2_add[0][0]
__________________________________________________________________________________________________
conv5_block3_1_conv (Conv2D)    (None, 7, 7, 512)    1049088     conv5_block2_out[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_conv (Conv2D)    (None, 7, 7, 512)    2359808     conv5_block3_1_relu[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_3_bn (BatchNormali (None, 7, 7, 2048)   8192        conv5_block3_3_conv[0][0]
__________________________________________________________________________________________________
conv5_block3_add (Add)          (None, 7, 7, 2048)   0           conv5_block2_out[0][0]
                                                                 conv5_block3_3_bn[0][0]
```

```
__________________________________________________________________________________________________
conv5_block3_out (Activation)   (None, 7, 7, 2048)   0           conv5_block3_add[0][0]
__________________________________________________________________________________________________
global_average_pooling2d (Globa (None, 2048)         0           conv5_block3_out[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 128)          262272      global_average_pooling2d[0][0]
__________________________________________________________________________________________________
dense_1 (Dense)                 (None, 3)            387         dense[0][0]
==================================================================================================
Total params: 23,850,371
Trainable params: 262,659
Non-trainable params: 23,587,712
__________________________________________________________________________________________________


2021-10-20 16:19:26.132916: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the ML
IR Optimization Passes are enabled (registered 2)

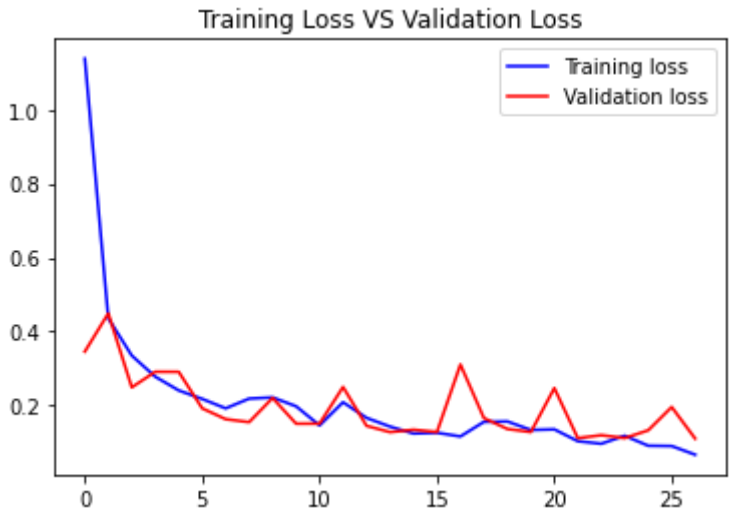

Epoch 1/50

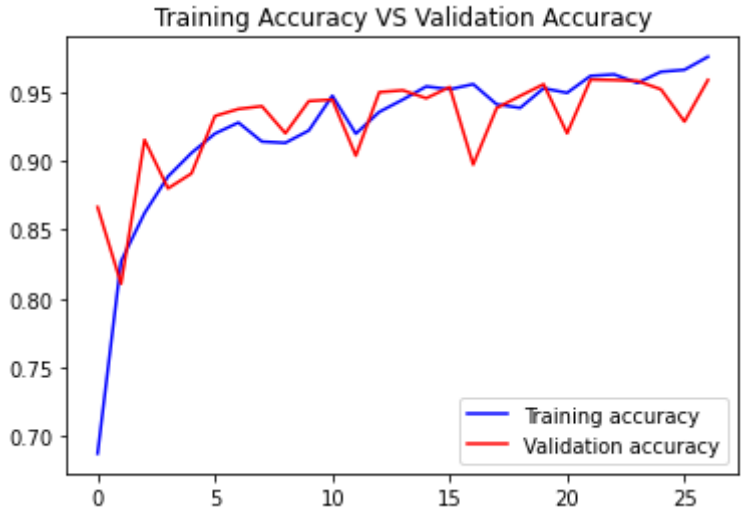

2021-10-20 16:19:30.752840: I tensorflow/stream_executor/cuda/cuda_dnn.cc:369] Loaded cuDNN version 8005
```

```
94/94 [==============================] - 113s 1s/step - loss: 1.1376 - accuracy: 0.6874 - val_loss: 0.3460
- val_accuracy: 0.8665
Epoch 2/50
94/94 [==============================] - 66s 707ms/step - loss: 0.4359 - accuracy: 0.8272 - val_loss: 0.44
94 - val_accuracy: 0.8108
Epoch 3/50
94/94 [==============================] - 66s 707ms/step - loss: 0.3353 - accuracy: 0.8622 - val_loss: 0.24
93 - val_accuracy: 0.9154
Epoch 4/50
94/94 [==============================] - 67s 707ms/step - loss: 0.2782 - accuracy: 0.8888 - val_loss: 0.29
14 - val_accuracy: 0.8801
Epoch 5/50
94/94 [==============================] - 67s 709ms/step - loss: 0.2410 - accuracy: 0.9059 - val_loss: 0.29
13 - val_accuracy: 0.8910
Epoch 6/50
94/94 [==============================] - 66s 705ms/step - loss: 0.2181 - accuracy: 0.9200 - val_loss: 0.19
27 - val_accuracy: 0.9327
Epoch 7/50
94/94 [==============================] - 67s 712ms/step - loss: 0.1926 - accuracy: 0.9280 - val_loss: 0.16
34 - val_accuracy: 0.9378
Epoch 8/50
94/94 [==============================] - 67s 707ms/step - loss: 0.2189 - accuracy: 0.9141 - val_loss: 0.15
54 - val_accuracy: 0.9399
Epoch 9/50
94/94 [==============================] - 66s 705ms/step - loss: 0.2221 - accuracy: 0.9132 - val_loss: 0.22
07 - val_accuracy: 0.9202
Epoch 10/50
94/94 [==============================] - 66s 702ms/step - loss: 0.1982 - accuracy: 0.9222 - val_loss: 0.15
12 - val_accuracy: 0.9436
Epoch 11/50
```

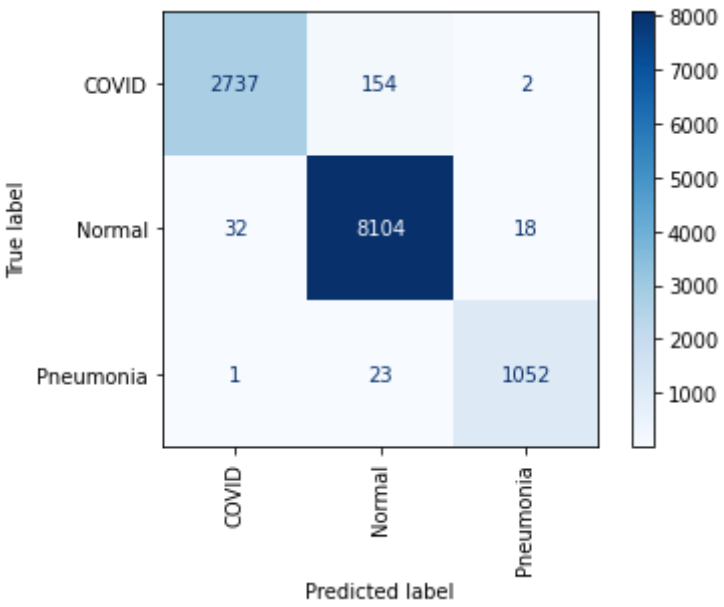
```
94/94 [==============================] - 66s 706ms/step - loss: 0.1466 - accuracy: 0.9475 - val_loss: 0.15
14 - val_accuracy: 0.9446
Epoch 12/50
94/94 [==============================] - 66s 701ms/step - loss: 0.2091 - accuracy: 0.9199 - val_loss: 0.25
04 - val_accuracy: 0.9039
Epoch 13/50
94/94 [==============================] - 66s 699ms/step - loss: 0.1669 - accuracy: 0.9357 - val_loss: 0.14
54 - val_accuracy: 0.9501
Epoch 14/50
94/94 [==============================] - 66s 703ms/step - loss: 0.1433 - accuracy: 0.9446 - val_loss: 0.12
84 - val_accuracy: 0.9514
Epoch 15/50
94/94 [==============================] - 66s 705ms/step - loss: 0.1247 - accuracy: 0.9542 - val_loss: 0.13
48 - val_accuracy: 0.9457
Epoch 16/50
94/94 [==============================] - 67s 707ms/step - loss: 0.1268 - accuracy: 0.9521 - val_loss: 0.12
87 - val_accuracy: 0.9538
Epoch 17/50
94/94 [==============================] - 67s 711ms/step - loss: 0.1167 - accuracy: 0.9559 - val_loss: 0.31
11 - val_accuracy: 0.8974
Epoch 18/50
94/94 [==============================] - 67s 710ms/step - loss: 0.1561 - accuracy: 0.9412 - val_loss: 0.16
63 - val_accuracy: 0.9385
Epoch 19/50
94/94 [==============================] - 67s 708ms/step - loss: 0.1573 - accuracy: 0.9386 - val_loss: 0.13
69 - val_accuracy: 0.9474
Epoch 20/50
94/94 [==============================] - 67s 710ms/step - loss: 0.1342 - accuracy: 0.9529 - val_loss: 0.12
86 - val_accuracy: 0.9558
Epoch 21/50
94/94 [==============================] - 67s 712ms/step - loss: 0.1359 - accuracy: 0.9496 - val_loss: 0.24
```

```
74 - val_accuracy: 0.9202
Epoch 22/50
94/94 [==============================] - 67s 708ms/step - loss: 0.1039 - accuracy: 0.9619 - val_loss: 0.11
21 - val_accuracy: 0.9592
Epoch 23/50
94/94 [==============================] - 67s 713ms/step - loss: 0.0970 - accuracy: 0.9630 - val_loss: 0.12
01 - val_accuracy: 0.9589
Epoch 24/50
94/94 [==============================] - 67s 709ms/step - loss: 0.1185 - accuracy: 0.9568 - val_loss: 0.11
23 - val_accuracy: 0.9582
Epoch 25/50
94/94 [==============================] - 67s 715ms/step - loss: 0.0916 - accuracy: 0.9649 - val_loss: 0.13
33 - val_accuracy: 0.9521
Epoch 26/50
94/94 [==============================] - 66s 706ms/step - loss: 0.0908 - accuracy: 0.9663 - val_loss: 0.19
62 - val_accuracy: 0.9287
Epoch 27/50
94/94 [==============================] - 67s 709ms/step - loss: 0.0674 - accuracy: 0.9758 - val_loss: 0.11
09 - val_accuracy: 0.9589
Epoch 00027: early stopping
```

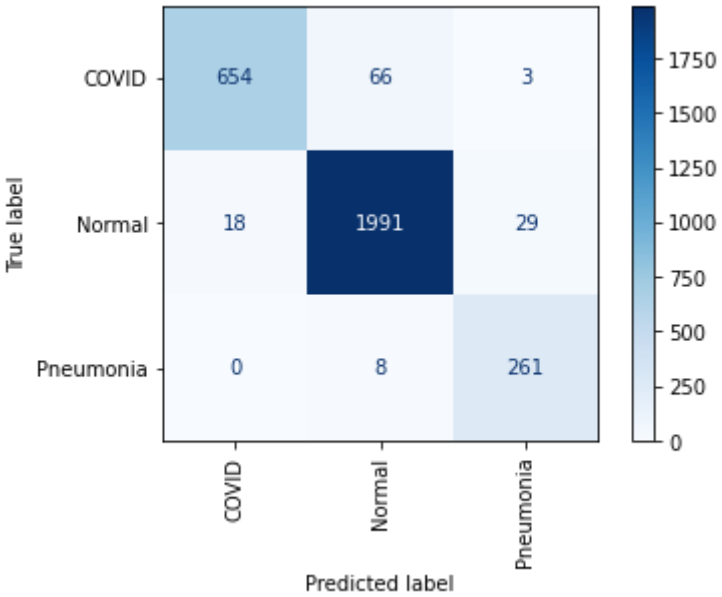

Training Loss VS Validation Loss
Training loss
Validation loss
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25


Training Accuracy VS Validation Accuracy
0.95
0.90
0.85
0.80
0.75
0.70
Training accuracy
Validation accuracy
0
5
10
15
20
25

```
Model saved successfully!
Confusion matrix for train data:
95/95 [==============================] - 54s 564ms/step - loss: 0.0542 - accuracy: 0.9810
Score = [0.05423067882657051, 0.9810277819633484]
Accuracy  =  0.9810277983997361
```




```
Confusion matrix for val/test data:
24/24 [==============================] - 13s 547ms/step - loss: 0.1101 - accuracy: 0.9591
Score = [0.11012284457683563, 0.959075927734375]
Accuracy  =  0.9590759075907591
```


COVID
Normal
Pneumonia
True label
654
66
3
18
1991
29
0
8
261
COVID
Normal
Pneumonia
Predicted label
1750
1500
1250
1000
750
500
250
0