IVP COURSE PROJECT REPORT

COVID-19 detection in Chest X-ray images using deep learning techniques

C3
Group Number - 10

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1. Abstract

Corona Virus Disease (COVID-19) is an infectious disease caused by a new virus that has not yet been detected in humans earlier. The virus causes a respiratory illness like the flu with various symptoms such as cough or fever, which can cause pneumonia in severe cases. COVID-19 is spreading rapidly among humans and at the time of writing (April 2020) has affected 1,200,000 people worldwide. In order to fight this disease, it is necessary to examine affected patients quickly and cheaply. One of the most viable steps towards this goal is a radiological examination, with a chest X-ray being the most readily available and cheapest option. This project aims to develop a rapid method for detecting COVID-19 in chest X-rays using deep learning techniques.

For this purpose, an object detection architecture is designed, trained, and tested using a publicly available dataset composed of many images of uninfected patients and patients infected with COVID-19. We have proposed a solution based on a deep convolutional neural network that can detect patients with COVID-19+ using chest X-rays. Several state-of-the-art CNN models – VGG16, VGG19, and ResNet50 – were adopted in the proposed work. We will also implement a custom CNN architecture model. These models will be individually trained to make independent predictions. And at the end, we compare the results for each approach for accuracy.

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2. Introduction and Motivation

The year 2020 was marked by a pandemic disease caused by a type of the coronavirus (CoV) family, called COVID-19 or SARS-CoV-2, which led to more than four million infections and more than 355,000 deaths worldwide.

Unlike other viruses, COVID-19 has a long incubation period, ranging from 3 days to 13 days, although the average time from exposure to onset of symptoms is approximately five to six days. The long incubation period makes COVID-19 more contagious because people carrying the virus will most likely continue to interact with other people until they realize they have the virus, leading to more infections. Furthermore, it has been reported that a few patients carrying the disease may show no symptoms at all (asymptomatic patients).

The most widely used method to test for the disease of Covid-19 is the RT-PCR test, which stands for a real-time reverse transcription-polymerase chain reaction. This method is usually time-consuming, as the process of performing the test along with transporting the samples takes more than half a day. The average processing time for this type of test is 3-6 days. On the other hand, CT and X-rays also help in detecting this disease in a short period of time. The use of X-ray image detection has a major advantage over CT scans because it is cost-effective, especially for underdeveloped and developing countries where resources are scarce.

Deep learning has changed the way we use data and how we perceive artificial intelligence. It is called deep learning because the networks have different layers and a large number of trainable parameters. Here we used a popular neural network called CNN (Convolution neuronal network) in our study. Another name for this is ConvNet. It mainly helps to process information that has the entire frame of a grid structure, such as an image. Images are made up of pixels that are arranged in a grid, and each grid has a unique value that describes the brightness and color of that pixel. The human brain has the ability to grasp information from images because each neuron works in its own receptive field.

The widespread use of CNNs for image classification tasks is due to the fact that they have demonstrated high accuracy in the areas of image recognition and object detection. Their success lies in their ability to capture the hidden features of images through their many hidden layers.

In this project, the main contributions are

- The effectiveness of several state-of-the-art pre-trained CNNs was evaluated with respect to the automatic detection of COVID-19 disease from chest X-ray images.

- A large number of CNN architectures have been used in an attempt to not only distinguish X-rays between COVID-19 patients and people without the disease but also distinguish pneumonia patients from coronavirus patients, which acts as a respiratory disease classifier.

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3. Problem Definition & Objectives

Problem Definition - COVID-19 detection in Chest X-ray images using deep learning techniques

Objectives -

- To obtain an easy way to detect Covid-19 easily from the Chest X-ray images
- To determine which Deep Learning Model will give accurate results for the given dataset so that it can be used to detect the disease for any random Chest X-ray accurately.

4. Literature Review

Sr. No	Author	Paper Title	Publication Year	Method/approach used	Dataset used	Achieved Performance	Advantages and Disadvantages	Future scope
1.	Nur-A-Alam, Mominul Ahsan , Md. Abdul Based, Julfikar Haider and Marcin Kowalski	COVID-19 Detection from Chest X-ray Images Using Feature Fusion and Deep Learning	2021	Machine vision Approach, Classification model through training by CNN (VGGNet), Histogram oriented gradient (HOG)	1. Cohen, J.P.; Morrison, P.; Dao, L. COVID-19 Image Data Collection. arXiv 2020, arXiv:2003.11597v1. , 2.COVID-19 X-ray Image Data Sets https://drive.google.com/uc?id=1coM7x3378f-Ou2l6Pg2wldaOI7Dntu1a	K-fold cross-validation showed that the developed feature fusion technique (98.36%) provided higher accuracy than the individual feature extraction methods, such as HOG (87.34%) or CNN (93.64%).	**Advantages-** Proposed feature fusion method using the deep learning technique assures a satisfactory performance with a testing accuracy of 99.49%, specificity of 95.7% and sensitivity of 93.65% **Disadvantages-** The limitation of this approach is that the less number of X-ray images. New images are continuously being made available around the world.	The future work will mainly focus on the fusion of HOG and CNN features for 3-D volume analysis. Further, many more efficient methods approaches can be developed by exploring other fusion approaches to improve the result.
2.	Amit Kumar Das,	Automatic COVID-19 detection from X-ray	2021	Deep Convolutional Neural Network-based	1.https://twitter.com/ChestImaging/status/1243928581983670	The proposed model has achieved a	Advantages - It yields a sensitivity of around 95%	More efficient methods can be

	Sayantani Ghosh, Samiruddin Thunder, Rohit Dutta, Sachin Agarwal, Amlan Chakrabarti	images using ensemble learning with convolutional neural network		solution, Multiple state-of-the-art CNN models—DenseNet201, Resnet50V2 and Inceptionv3	272. 2.https://www.sirm.org/category/senza-categoria/COVID-19/ . 3.https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia	classification accuracy of 91.62%.	for COVID +ve cases i.e., out of 100 COVID +ve patients, more than 95 can be correctly diagnosed by our proposed model. Disadvantages - The limitation of this study is the small number of X-ray images.	developed by exploring other fusion approaches to improve the accuracy.
3	Joy Iong-Zong Chen	Design of Accurate Classification of COVID-19 Disease in X-Ray Images Using Deep Learning Approach	2021	Histogram-oriented gradients (HOG), CNN classification method	1.https://github.com/agchung/Figure1-COVIDchestxray-dataset 2. Cohen JP, Morrison P, Dao L (2020) COVID-19 image data collection. arXiv:2003.11597	The proposed model has achieved 85% accuracy of tertiary classification that includes normal, COVID-19 positive.	Advantages - The proposed algorithm obtains good classification accuracy during the binary classification procedure integrated with the transfer learning method. Disadvantages - Limited dataset issues.	In the future development of the proposed framework will be extended to similar infectious diseases such as bacterial pneumonia by using X-ray images.

4	Antonios Makris, Ioannis Kontopoulos , Konstantinos Tserpes	COVID-19 detection from chest X-Ray images using Deep Learning and Convolutional Neural Networks	2020	A deep CNN model able to predict the coronavirus disease from chest X-ray images is given. The proposed CNN is based on pre-trained transfer models in order to obtain high accuracy in prediction from a small sample of X-ray images.	1. Chest X-Ray Images (Pneumonia), https://www.kaggle.com/paultimothymooney/Chest-xray-pneumonia 2. https://github.com/AntonisMakris/COVID19-XRay-Dataset 3. https://keras.io/api/applications/	1. The results suggest that the VGG16 and the VGG19 achieve the best classification accuracy of 95%. 2. The NASNetLarge model showed a moderate accuracy of 81%. 3. The other models did not surpass 80% of accuracy with MobileNet V2 and DenseNet 201 presenting the lowest results with 40% and 38% accuracy respectively.	**Advantages-** Deep learning techniques are employed on chest radiography images with a view to detect infected patients and the results have been shown to be quite promising in terms of accuracy. **Disadvantage** One of the major disadvantages of CNN in deep learning is to identify covid-19 virus in early stages as limited data analysis.	For future work, We intend to train the CNNs on more data and to evaluate many more architectures for the case of COVID-19 detection

5	Emtiaz Hussain , Mahmudul Hasan, Md Anisur Rahman, Ickjai Lee, Tasmi Tamanna,Mohammad Zavid Parvez	CoroDet: A deep learning based classification for COVID-19 detection using chest X-ray images	2021	A novel CNN model called CoroDet for automatic detection of COVID-19. CoroDet is developed to serve as an accurate diagnostics for 2 class classification (COVID and Normal), 3 class classification (COVID, Normal, and non-COVID pneumonia), and 4 class classification (COVID, Normal, non-COVID viral pneumonia, and non-COVID bacterial pneumo nia).	1. Cohen JP . Covid-chestxray-dataset. Apr 2020 GitHub - ieee8023/covid-chestxray-dataset: We are building an open database of COVID-19 cases with chest X-ray or CT images. 2. UCSD-AI4H . COVID-CT. Apr 2020 GitHub - UCSD-AI4H/COVID-CT: COVID-CT-Dataset: A CT Scan Dataset about COVID-19 3.https://www.kaggle.com/plamenedu ardo/sarscov2-ctscan- dataset	Accuracy of the proposed CoroDet method with previously published techniques for 4 class classification, 3 class classification, and 2 class classification for COVID-19 detection. Here also provide an empirical justification for our proposed 22-layer model. Moreover, the outcomes of the CoroDet method is evaluated by a physician in or- der to demonstrate the performance of CoroDet more	**Advantages-** The experimental results of our proposed method CoroDet indicate the superiority of CoroDet over the existing state-of-the-art -methods. CoroDet may assist clinicians in making appropriate decisions for COVID-19 detection and may also mitigate the problem of scarcity of testing kits. **Disadvantages-** The one only disadvantage of the method is we need a larger amount of dataset for more accuracy. If you have limited dataset it may reduce accuracy.	In future we can say in this we find best accuracy for different class covid-19

						precisely		
6	Shamima Akter, F. M. Javed Mehedi Shamrat, Sovon Chakraborty , Asif Karim, Sami Azam	COVID-19 Detection Using Deep Learning Algorithm on Chest X-ray Images	2021	Deep learning-based classification model, based on a Convolutional Neural Network, that demonstrates a rapid detection rate for COVID-19	Data Availability : https://www.kaggle.com/tawsifurrahman/covid19-radiographydatabase?fbclid=IwAR0rw_prTvf9R0zInrJQkTFazeBaESxh3rB6otdrPdAWJDonEbIl2Nf6epk	The highest performance achieved by the existing models is from Biology 2021, 10, 1174 21 of 23 MobileNetV2. The existing MobileNetV2 model has an accuracy of 97% in classifying COVID-19 and healthy chest X-rays in 5 h 42 min 34 s. The precision, recall, sensitivity, and F1 score of this model are 96%, 97%, 96% and 96%, respectively	**Advantages-** The study attempts to understand the specific strengths and weaknesses of common deep learning models in order to identify COVID-19 with acceptable accuracy When trained and tested on a large dataset, are outperformance by the proposed modified model in COVID-19 detection. The classification accuracy of the modified MobileNetV2 model is 98% in 2 h 50 min 21 s **Disadvantages-** The limitation of this study is the small number of	Future work, the proposed method could be implemented on a dataset with more classes of pulmonary diseases such as asthma, chronic obstructive pulmonary disease, pulmonary fibrosis, pneumonia, lung cancer and COVID-19

							X-ray images.	
7	DandiYang, Cristhian Martinez, LaraVisuña , Hardev Khandha, Chintan Bhatt3 Jesus Carretero	Detection and analysis of COVID-19 in medical images using deep learning techniques	2021	CNN models, the datasets used in this paper, the evaluation metrics, and the experimental setup for each analysis performed.	The used datasets were obtained from publicly open-source datasets from: COVID-19 Radiography Database https://www.kaggle.com/tawsifurrahman/covid19-radiography-database; OCT and Chest X-Ray Images https:// data.mendeley.com/datasets/rscbjbr9sj/3; SARS-CoV-2 CT Scan Dataset https://www.kaggle.com/plamenedua rdo/sarscov2-ctscan-dataset.	With an extensive evaluation to validate the proposed methods, we found the proposed VGG16 deep transfer learning model shows excellent performance on binary and three-class classifcation tasks, the accuracy of the best model is as high as 99%	**Advantages-** The model has a very high accuracy (99%) distinguishing Pneumonia, particularly viral pneumonia, from COVID-19 **Disadvantages-** Limited number of training images in deep learning. Owing to the lack of a public COVID-19 dataset, we prepared a dataset containing 3616 chest X-ray images of COVID-19 positive patients.	As future research lines, we are already working on multi-criteria classification to distinguish images from datasets mixing patients with lung problems due to several possible diseases, such as tuberculosis, AIDS, COVID19, etc

8	Aijaz Ahmad Reshi , Furqan Rustam, Arif Mehmood , Abdulaziz Alhossan, Ziyad Alrabiah , Ajaz Ahmad , Hessa Alsuwailem, and Gyu Sang Choi	An Efficient CNN Model for COVID-19 Disease Detection Based on X-Ray Image Classification	2021	A deep CNN architecture has been proposed in this paper for the diagnosis of COVID-19 based on the chest X-ray image classification	P. Mooney, "Kaggle X rays dataset," 2020, https://www.kaggle. com/paultimothymooney/chest-xray-pneumonia Online	The performance in this test scenario was as high as 99.5%.	Advantages – This study has been conducted to show how effective the diagnosis of COVID-19 using CNN which was trained on chest X-ray image datasets. model training was performed incrementally with various new datasets to attain the maximum level of accuracy and performance. Disadvantages – The primary dataset was very limited/small in size and also imbalanced in terms of class distribution.	Considering the significant effect of data augmentation techniques on model performances, the authors of the paper are currently working on the application of other state-of-the art data augmentation algorithms and techniques

5. Methodology

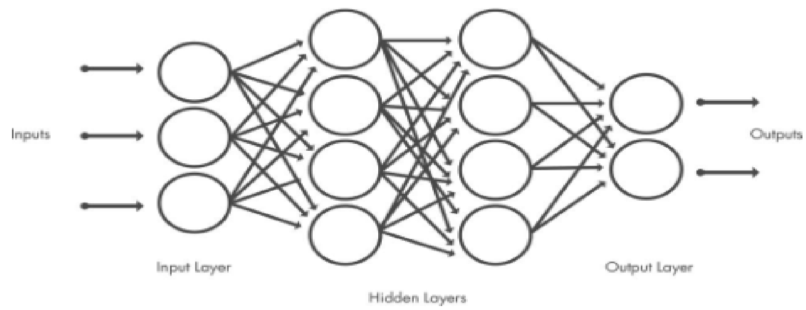
Numerous studies have used Convolutional Neural Networks for the problem of image classification in the literature, most of which create different architectures for the neural networks. Deep convolutional neural networks are one of the powerful deep learning architectures and have been widely applied in a broad range of machine learning tasks.

Convolutional Neural Network (CNN)-

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm that can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image, and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets have the ability to learn these filters/characteristics.

The architecture of a ConvNet is analogous to that of the connectivity pattern of Neurons in the Human Brain and was inspired by the organization of the Visual Cortex. Individual neurons respond to stimuli only in a restricted region of the visual field known as the Receptive Field. A collection of such fields overlap to cover the entire visual area.

Like other neural networks, a CNN is composed of an input layer, an output layer, and many hidden layers in between.

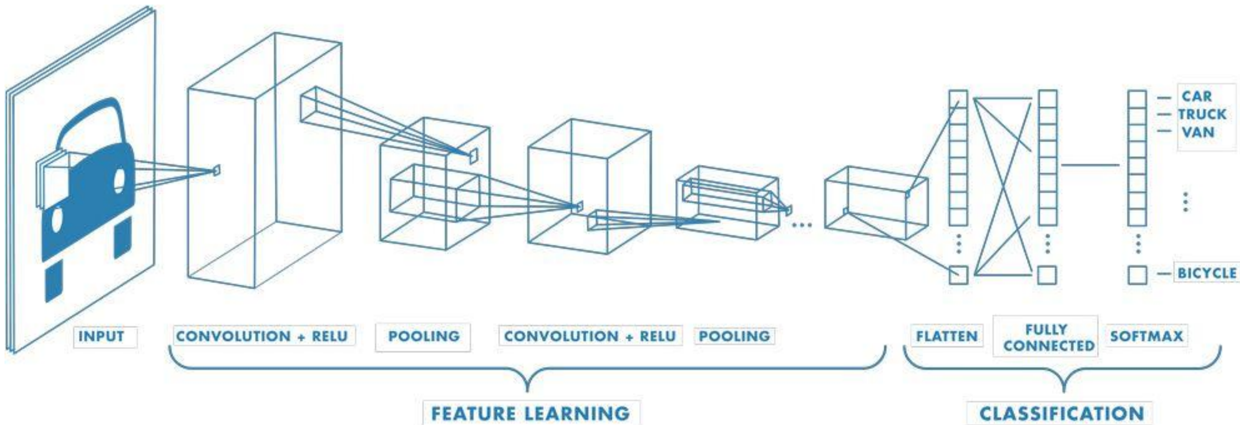


Img-1

These layers perform operations that alter the data with the intent of learning features specific to the data. Three of the most common layers are convolution, activation or ReLU, and pooling.

- Convolution puts the input images through a set of convolutional filters, each of which activates certain features from the images.
- Rectified linear unit (ReLU) allows for faster and more effective training by mapping negative values to zero and maintaining positive values. This is sometimes referred to as activation because only the activated features are carried forward into the next layer.
- Pooling simplifies the output by performing nonlinear downsampling, reducing the number of parameters that the network needs to learn.

These operations are repeated over tens or hundreds of layers, with each layer learning to identify different features.



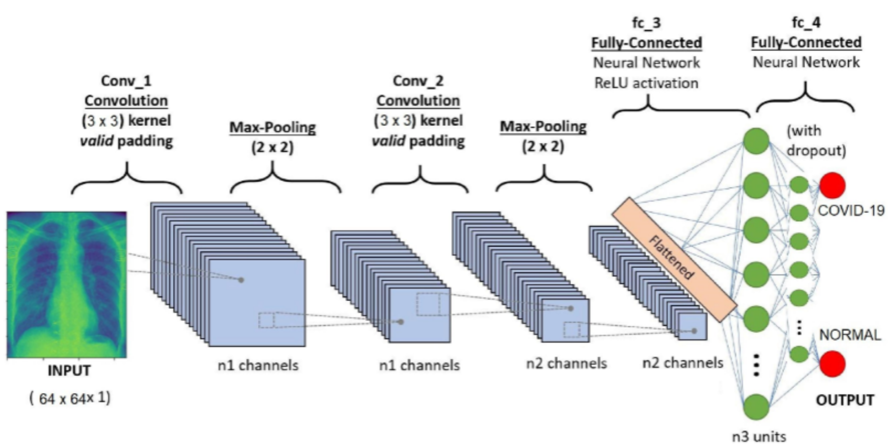
Img - 2

Example of a network with many convolutional layers. Filters are applied to each training image at different resolutions, and the output of each convolved image is used as the input to the next layer.

Convolutional Neural Network (CNN) for COVID-19 Detection

Various research studies already exist for COVID-19 detection. For the most part, deep learning techniques are employed on chest radiography images with a view to detecting infected patients and the results have been shown to be quite promising in terms of accuracy.

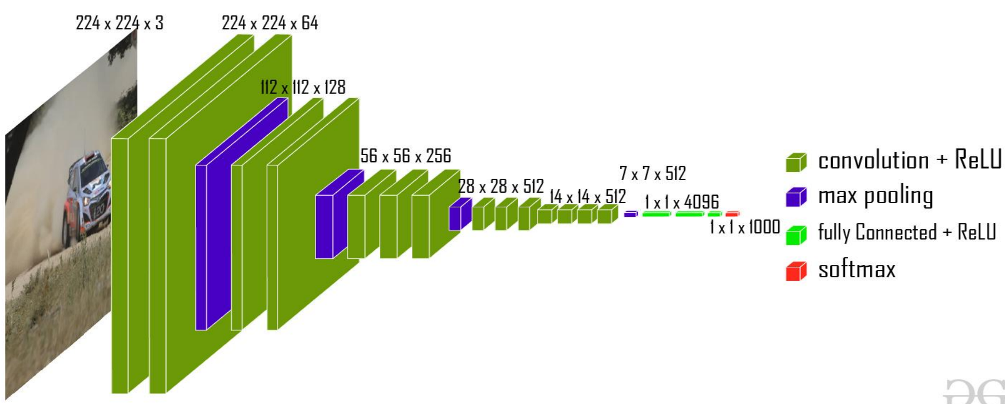
Our project aims to create a solution that can easily detect covid-19 in an automated way, especially when the need for auxiliary diagnostic tools has increased as there are no accurate automated toolkits available.



Img-3

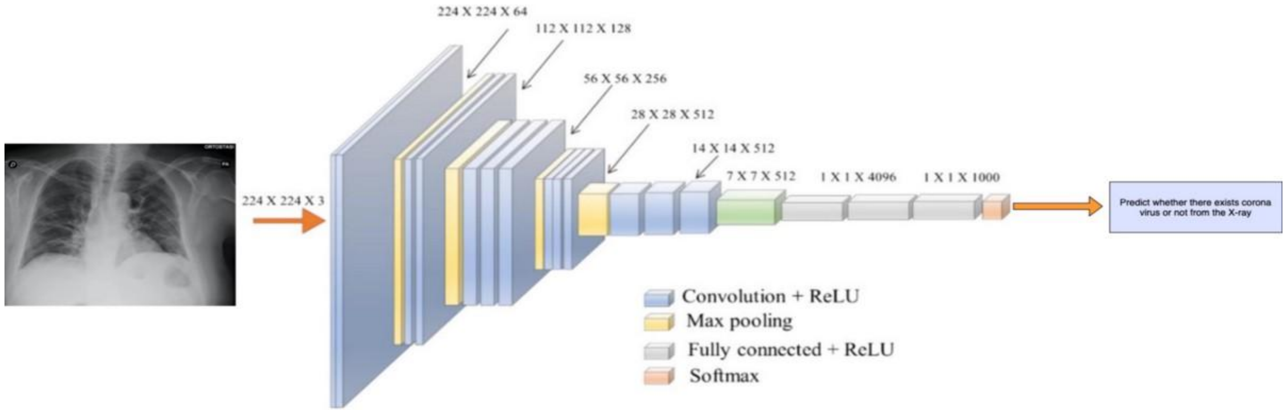
The proposed CNN is based on pre-trained transfer models such as VGG16, VGG19, and ResNet50 as well as our own architectural model in order to obtain high prediction accuracy from a small sample of X-ray images. The images are classified into two classes, No_findings/normal and Covid-19.
To overcome the insufficient data and training time, a transfer learning technique is applied by employing the ImageNet dataset. The implementation will use Keras with a TensorFlow backend, which will be performed, then adapted to our dataset full of X-ray images in Covid-19 and No_findings folders.

VGG16 - VGG-16 is a convolutional neural network that is 16 layers deep. You can load a pre-trained version of the network trained on more than a million images from the ImageNet database. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals. As a result, the network has learned rich feature representations for a wide range of images. The network has an image input size of 224-by-224.



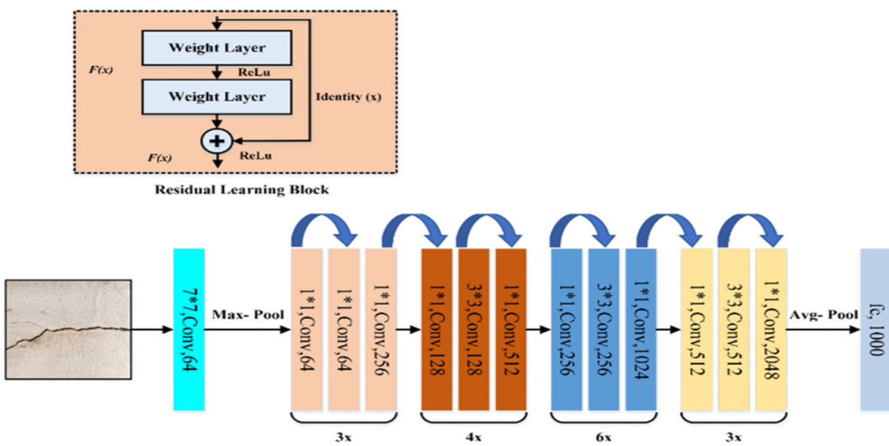
Img-4 - (VGG-16 architecture)

VGG-19 - VGG-19 is a convolutional neural network that is 19 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals. As a result, the network has learned rich feature representations for a wide range of images. The network has an image input size of 224-by-224.



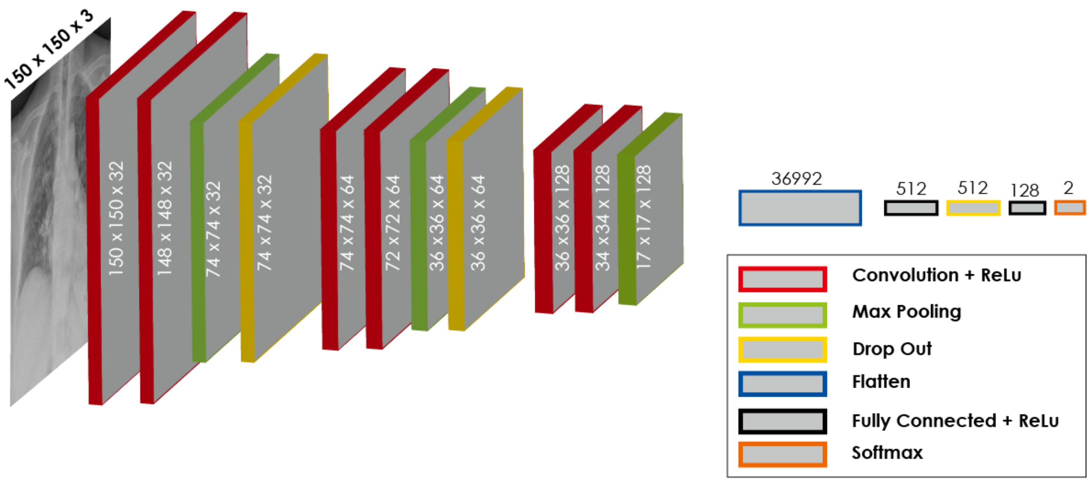
Img-5 - (VGG-19 architecture)

ResNet50 - ResNet-50 is a convolutional neural network that is 50 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database. The pretrained network can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals. As a result, the network has learned rich feature representations for a wide range of images. The network has an image input size of 224-by-224.



Img-6 - (ResNet50 architecture)

Our Own Architecture -



Img-7

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6. Software & Hardware Requirements

Software Technologies Required -

- Python (latest version)
- Or Google Colab Or Jupyter Notebook for running ipynb file
- Other important libraries required will be -
    - TensorFlow
    - Keras
    - Scikit-Learn (sklearn)
    - Pandas
    - Numpy
    - Matplotlib (pyplot)
    - seaborn

Hardware Requirements

- Graphics Card / GPU (if possible) (Google Colab will perform better)

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7. Implementation

The implementation will use Keras with a TensorFlow backend, which will be performed, then adapted to our dataset full of X-ray images in Covid-19 and No_findings folders.

1. ResNet50 Model Architecture -

- Data preprocessing and exploring
    - Access Files in Drive (We will we accessing the DataSet files from google drive having X-ray images in Covid-19 and No_findings folders)
    - Import required libraries and necessary packages
    - Load The data (We will see, our data set, contains two folders, Covid-19 which contains X-ray images of people caught up with the virus, the No_findings which contains X-ray images of normal people)
    - Convert images to arrays.
    - We look at some pictures just for testing.
    - Converting a class vector (integers) to the binary class matrix.
    - Split the data into train, test, and valid subsets

- CNN Implementation
    - Fine-tuning RestNet50 pre-trained model (Here we are going to use Transfer Learning)
    - BatchNormalization
    - Compile the model (using adam optimizer)
    - Modelling(100 epochs)
- Evaluations and results
    - Evaluation
    - Accuracy and Loss graphs
    - Prediction
    - Confusion Matrix
    - Loading the model (Here we're gonna load our best model trained before, then make some predictions with it !)

2. VGG16 Model Architecture

- Data preprocessing and exploring
    - Access Files in Drive (We will we accessing the DataSet files from google drive having X-ray images in Covid-19 and No_findings folders)
    - Import required libraries and necessary packages
    - Load The data (We will see, our data set, contains two folders, Covid-19 which contains X-ray images of people caught up with the virus, the No_findings which contains X-ray images of normal people)

- Convert images to arrays.
    - We look at some pictures just for testing.
    - Converting a class vector (integers) to the binary class matrix.
    - Split the data into train, test and valid subsets

- CNN Implementation
    - Fine-tuning VGG16 pre-trained model (Here we are going to use Transfer Learning)
    - Head Model (Sequential method)
    - Final Model
    - Compile the model (using adam optimizer)
    - Modelling (using the model.fit_generator)(100 epochs)

- Evaluations and results
    - Evaluation
    - Accuracy and Loss graphs
    - Prediction
    - Confusion Matrix
    - Loading the model (Here we're gonna load our best model trained before, then make some predictions with it !)

3. VGG19 Model Architecture

- Data preprocessing and exploring
    - Access Files in Drive (We will we accessing the DataSet files from google drive having X-ray images in Covid-19 and No_findings folders)
    - Import required libraries and necessary packages
    - Load The data (We will see, our data set, contains two folders, Covid-19 which contains X-ray images of people caught up with the virus, the No_findings which contains X-ray images of normal people)
    - Convert images to arrays.
    - We look at some pictures just for testing.
    - Converting a class vector (integers) to the binary class matrix.
    - Split the data into train, test and valid subsets

- CNN Implementation
    - Fine-tuning VGG19 pre-trained model (Here we are going to use Transfer Learning)
    - BatchNormalization
    - Final Model
    - Compile the model (using adam optimizer)

- Modelling (using the model.fit_generator)(100 epochs)

- Evaluations and results
    - Evaluation
    - Accuracy and Loss graphs
    - Prediction
    - Confusion Matrix
    - Loading the model (Here we're gonna load our best model trained before, then make some predictions with it !)

4. Our Own Model Architecture -

- Data preprocessing and exploring
    - Access Files in Drive (We will we accessing the DataSet files from google drive having X-ray images in Covid-19 and No_findings folders)
    - Import required libraries and necessary packages
    - Load The data (We will see, our data set, contains two folders, Covid-19 which contains X-ray images of people caught up with the virus, the No_findings which contains X-ray images of normal people)
    - Convert images to arrays.
    - We look at some pictures just for testing.
    - Converting a class vector (integers) to the binary class matrix.
    - Split the data into train, test, and valid subsets

- CNN Implementation
    - Getting required libraries and setting up the CNN model by changing various hyper-parameters.
    - Compile the model (using the RMSpro optimizer)
    - Modelling (100 epochs)

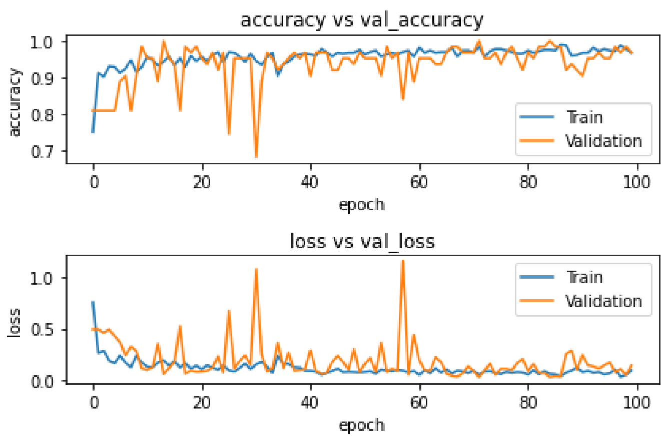
- Evaluations and results
    - Evaluation
    - Accuracy and Loss graphs
    - Prediction
    - Confusion Matrix
    - Loading the model (Here we're gonna load our best model trained before, then make some predictions with it !)

8. Results

a.ResNet50 -

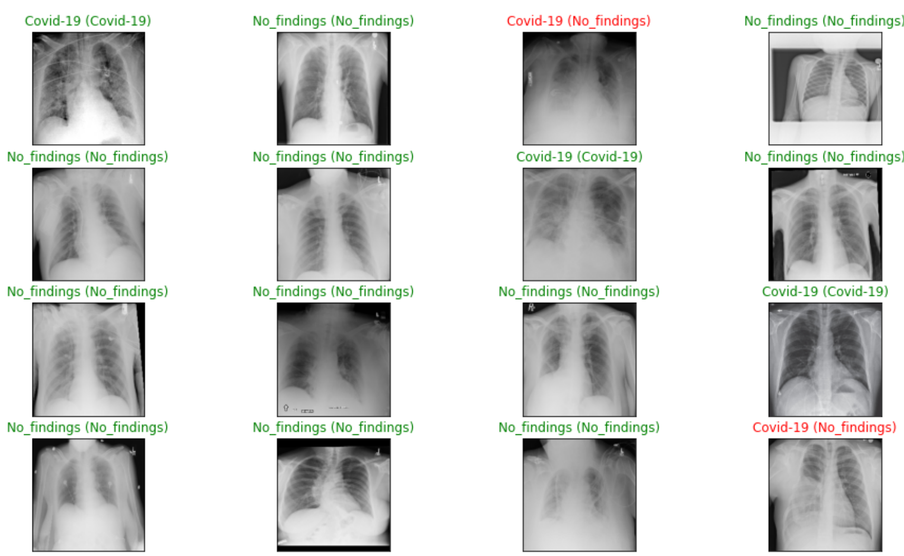
The Test accuracy for ResNet50 is 91.94%
and the Test Loss is 0.1510939747095108.

train/validation Accuracy and Loss graphs -



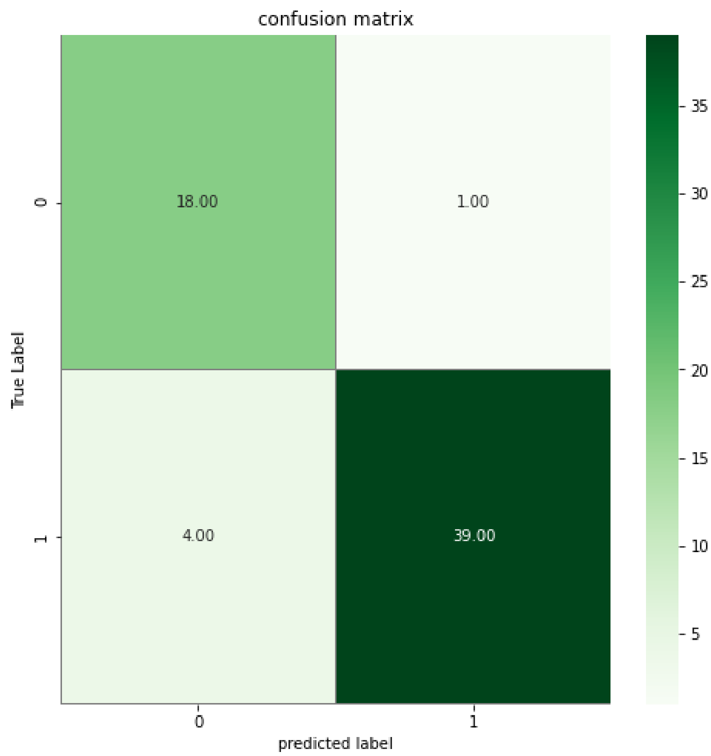
Img-8

test of our model against more random samples from the test data -



Img-9

Confusion Matrix
— Please note that 0 and 1 values represent Covid-19 and No_findigs respectively.

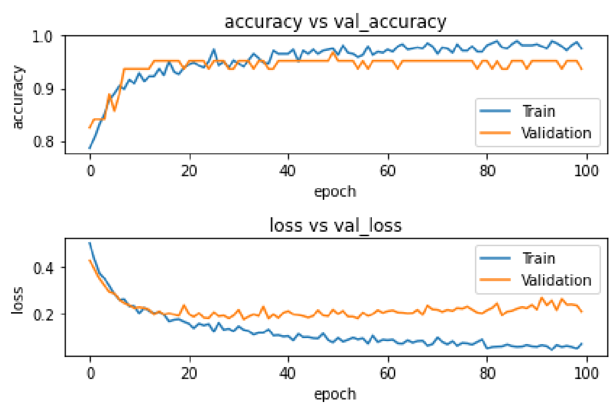


Img-10

b.VGG16 -

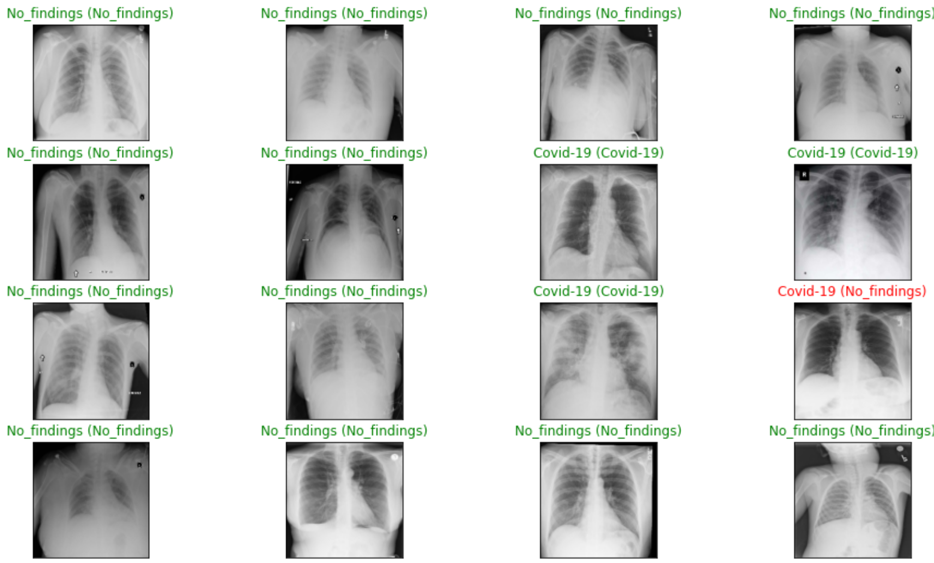
The Test accuracy for VGG16 is 96.77%
and the Test Loss is 0.09637050330638885.

train/validation Accuracy and Loss graphs -



Img-11

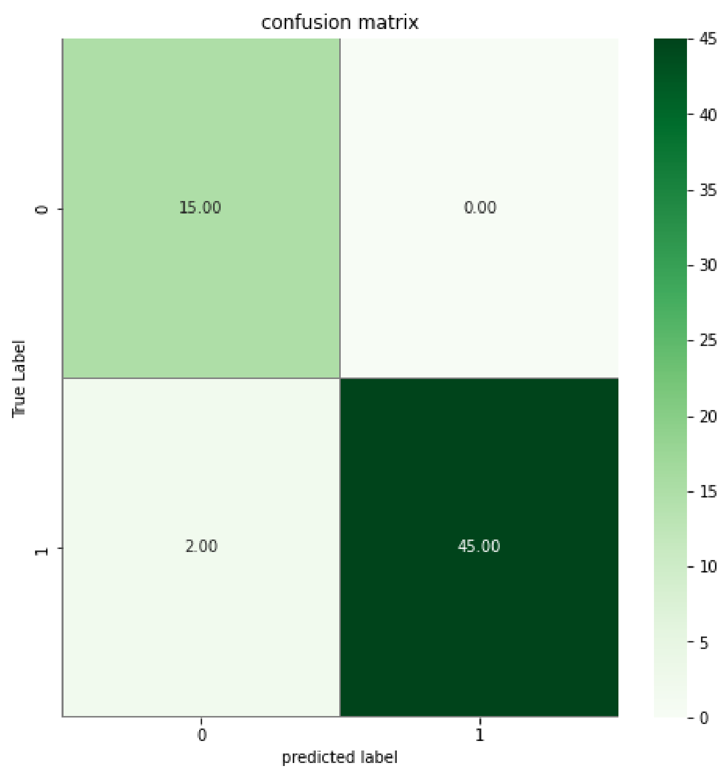
test of our model against more random samples from the test data -



Img-12

Confusion Matrix

— Please note that 0 and 1 values represent Covid-19 and No_findigs respectively.

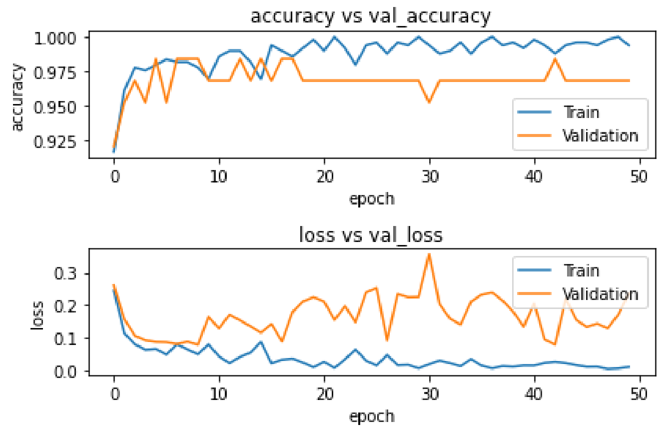


Img-13

c.VGG19 -

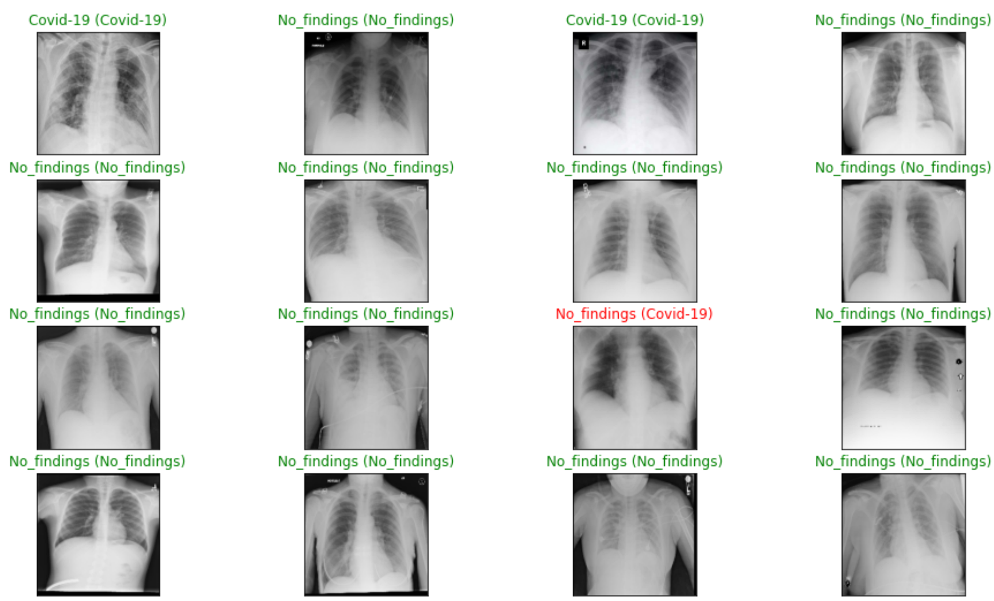
The Test accuracy for VGG19 is 98.39%
and the Test Loss is 0.10685943067073822

train/validation Accuracy and Loss graphs -



Img-14

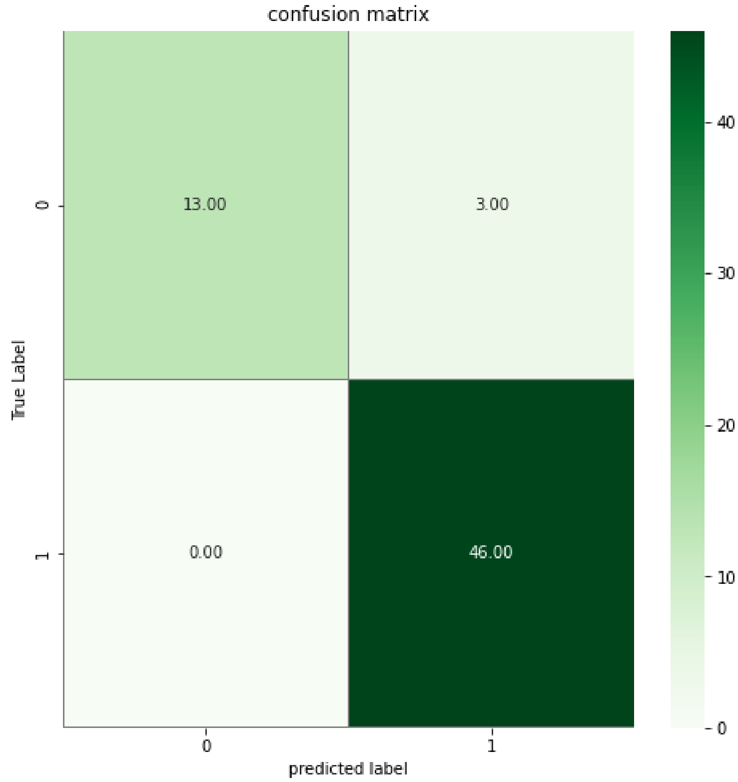
test of our model against more random samples from the test data -



Img-15

Confusion Matrix

— Please note that 0 and 1 values represent Covid-19 and No_findigs respectively.

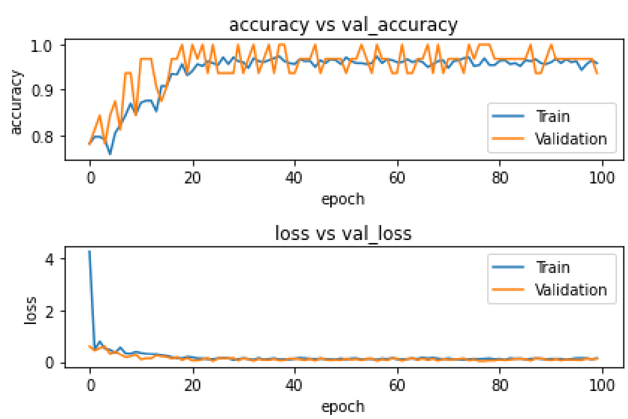


Img-16

d. Our Own Architecture Model -

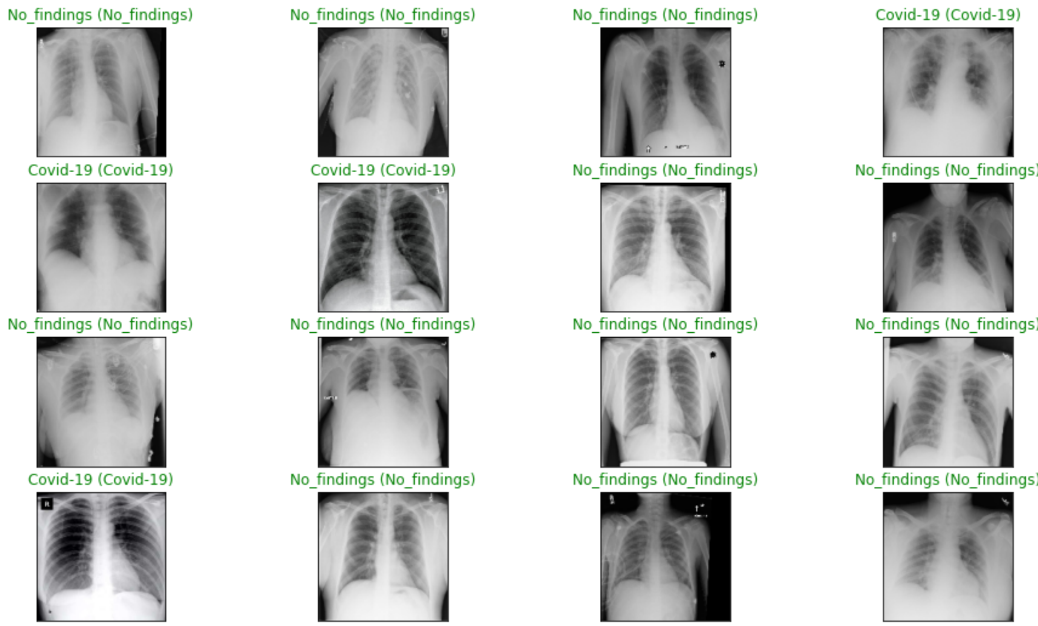
The Test accuracy for this model is 95.16%
and the Test Loss is 0.13708597421646118

train/validation Accuracy and Loss graphs -



Img-17

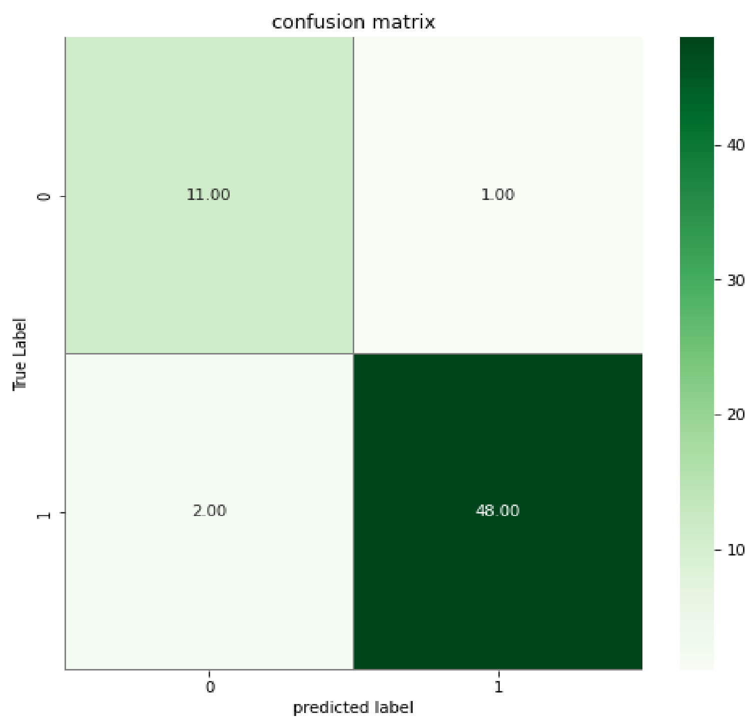
test of our model against more random samples from the test data -



Img-18

Confusion Matrix

— Please note that 0 and 1 values represent Covid-19 and No_findigs respectively.



Img-19

9. Comparison

So from the above data we get -

Model	Test Accuracy	Test Loss
ResNet50	91.94%	0.1510939747095108
VGG16	96.77%	0.09637050330638885
VGG19	98.39%	0.10685943067073822
Own Architecture Model	95.16%	0.13708597421646118

So from above analysis we can say that VGG19 is most accurate for the given dataset to detect COVID-19 from chest X-RAYS.

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10. Conclusion

We implemented a methodology for the detection of the presence of the Covid-19 virus in a human body by processing chest X-Ray images through our ML models. The CNN models – VGG16, VGG19, and ResNet50 have given an accuracy of 96.77%, 98.39%, and 98.39% and the custom model we have created by ourselves gives an accuracy of 95.16%. The significant limitation of our study was the unavailability of high-quality covid-positive images and limited images. Due to this limitation, we had to make use of a large number of trainable parameters. If this weren't the case, then we could have attained better results for a lesser number of epochs, and this could have significantly reduced our training time. On the brighter side, all the models can be used effectively in remote places having a shortage of medical experts and/or unavailability of testing kits.

For the future, this deep learning architecture needs to be trained on a wider variety of publicly available datasets so that the performance can yield promising results. In addition to that, it can also help in identifying other chest-related diseases such as Bronchiectasis and SARS. With the help of hospital staff, medical experts, and researchers, we aim to make this model more effective and robust by gathering an ample amount of data for future use. We hope our work inspires others so they may help in improving the accuracy and overall contributing to the community.

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