Analysis of Deep Learning algorithms on COVID-19 Radiography Database

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Abstract

The Coronavirus disease, caused by severe acute respiratory syndrome coronavirus 2(SARS-CoV-2) virus is obstreperous in large parts of the world. Various techniques like genome sequencing, tomography imaging, and electron microscopy were used initially to detect the presence of COVID19 but these techniques take more a day time to produce the result. This paper aims to analyze the various deep learning algorithms on the radiography database that could be useful in diagnosing the COVID19 existence. CNN has achieved a lot in various fields of computer vision problems in recent years. CNN architectures used in this experimental analysis include basic models like simple CNN, LeNet5 in continuation with large models like VGG, DenseNet, ResNet, Inception, NasNet, and MobileNet. Further, a majority rule has been proposed where decision produced by all networks will be in consideration to derive final results. One can take the top five models based on an accuracy metric and involve them in voting. COVID-19 detection will be termed as positive when more than 50% nodes are in favour otherwise it will be termed as negative. As the number of cases is rising at a rapid rate, so the medical community isn't able to tackle the problem effectively. Hence there is a need for fast and reliable means for quick diagnostic of the virus. This novel approach presented will be crucial in large population screening, the prognosis of the inflection, prioritizing the use and allocation of limited resources available specifically in developing countries. It will also help design targeted responses within the limited time frame (of a few minutes) and lower cost as compared to typical existing testing procedures available.

Keywords: VGG, DenseNet, ResNet, Inception, NasNet, MobileNet

1. INTRODUCTION

Coronaviruses are a family of enveloped, single-stranded, positive-strand RNA viruses that are important viral pathogens and classified within the Nidovirals order. Four types of coronaviruses are present, of which two are important causes of infections in humans including the recent isolated severe acute respiratory syndrome coronavirus(SARS-CoV). Coronavirus has been described for more than 7 decades, i.e. the isolation of murine coronavirus strain JHM as reported in 1949. However, in 2003, 770 deaths happened due to a new coronavirus was responsible for the severe acute respiratory syndrome(SARS), coronavirus becomes much more recognized.

Later in 2004 and 2005 HCoV-NL63 and HCoV-HKUI strains were discovered which caused severe bronchiolitis and upper respiratory tract infection. In 2012 MERS was discovered which was transmitted from animals to humans and caused more than 850 deaths. SARS-CoV-2 discovered at the end of 2019 mark as the more severe than any other coronavirus because of its easily transmissible property and no pre-existing immunity about the virus. Moreover, it harms the lower respiratory tract (Trachea, Primary bronchi, Lungs) along with the upper respiratory tract (Nasal Cavity, Pharynx, Larynx). Infection is transmitted mostly by droplets (microscopic bits of phlegm, saliva or mucous) landing on the mouth, nose or eyes. Symptoms can range from mild to severe and mostly in older people, have hypertension or diabetes, or heart or lung disease.

This virus was initially originated from Wuhan city in China when the Chinese official reported WHO about pneumonia-like cases in the Wuhan city in Dec 2019. The first official death from this Coronavirus was reported by China in Jan 2020. Further this virus spread to the whole world and causing a pandemic in all continents. More than 23 lakhs people have been infected all around the globe causing more than 1.5 lakhs deaths, resulting in the total lockdown in various counties.

This coronavirus doesn't have any vaccine available for its treatment till now. Staying away from the virus is the primary precaution that can be taken. So the detection of the COVID19 presence is the necessity and that too at a larger scale which will help us in making precaution a primary way.

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2. RELATED WORK AND DATASET

In the era of this latest technology incredible computational power and effective applications begin with data. Data serves as the driving fuel in the field of artificial intelligence and are the foundation element at every perspective. Moreover, data in good structure and labelling form i.e. descriptive, diagnostic, prescriptive and predictive is necessary which can prove as the establishment of a robust system. Various organizations in the world are coming out with the COVID19 dataset. These data are of various types like textual counts, genome sequence, 2d structure and various features like patient's age, sex, location, symptoms, etc. We have chosen an x-ray image dataset for are diagnosing purposes. Various sources of this collected data are from the following sources:

1. https://www.kaggle.com/khoongweihao/covid19-xray-dataset-train-test-sets
2. https://www.kaggle.com/tawsifurrahman/covid19-radiography-database
3. https://www.kaggle.com/kimjihoo/coronavirusdataset
4. Research university websites and official government online platforms
5. Some repository on the GitHub like https://github.com/ieee8023/covid-chestxray-dataset, https://github.com/midas-network/COVID-19, etc. has also helped in providing some viewpoints in our work.

When it comes to using the AI in the healthcare field data should be more precise and accurate as various consequences can happen due to fluctuation for even in single value to the prediction. Earlier work through various websites and blogs on COVID19 detection has used very fewer amount of data[1]. We presented a deep learning-based segmentation to identify different ROI areas in the x-ray images and generating a sequence structure or pattern to detect in the testing stage with new data. Various CNNs architecture has been tested and the result has been shown in this paper.

3. DEEP LEARNING ARCHITECTURES FOR COVID-19

Deep Learning is the subset of Machine Learning that imitates in processing data and creating patterns for use in decision making. Deep Learning has achieved enormous success in applications such as anomaly detection, image detection, pattern recognition, and NLP tasks. They are also capable of learning from an unsupervised form of data which can be called deep neural networks. Various popular deep learning architectures [2-6] include Convolutional Neural Network, Recurrent Neural Network, Deep Belief Network, Long Short Term Memory, Transformers. Deep Neural Network has achieved tremendous progress in the past decades which can be seen in Figure1. We have used 14 of these architectures for our COVID19 analysis and diagnosing. These architectures include various forms of Lenet, VGG, DenseNet, ResNet, Inception, MobileNet, and Xception. As per the current study chest x-ray can be used in diagnosing the disease. Now, let's move forward in expanding all the architectures one by one. CNN is a type of neural network that uses the convolutional layer, activation layer, pooling layer in its hidden layers, fully dense layer and output layer is used to predict.

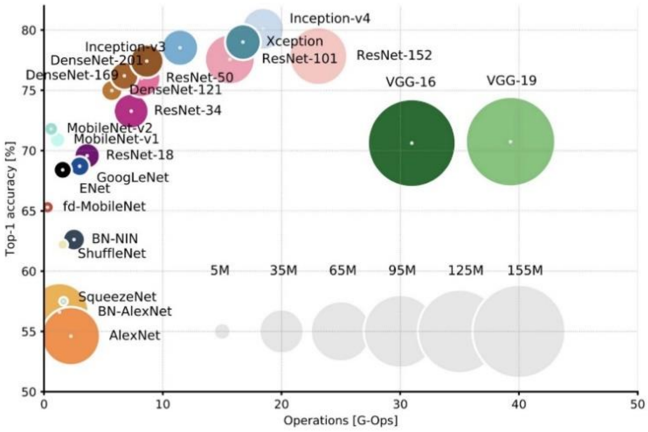

Figure1: Variations in Neural Network Architecture with Top-1 accuracy [https://images.app.goo.gl/nddCxVZjpKDHwhUU9]

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A 5 layer CNN architecture accompanied by a fully connected layer with an output layer is used by us. CNN takes an image as input, assign weights and baise to differentiate between images. Result of CNN is seen in Figure2. LeNet5 is a two-layer convolutional architecture style neural network followed with a fully connected layer and softmax activation. This is the simplest model used by us in the COVID19 prediction. Result of LeNet5 is seen in Figure3.

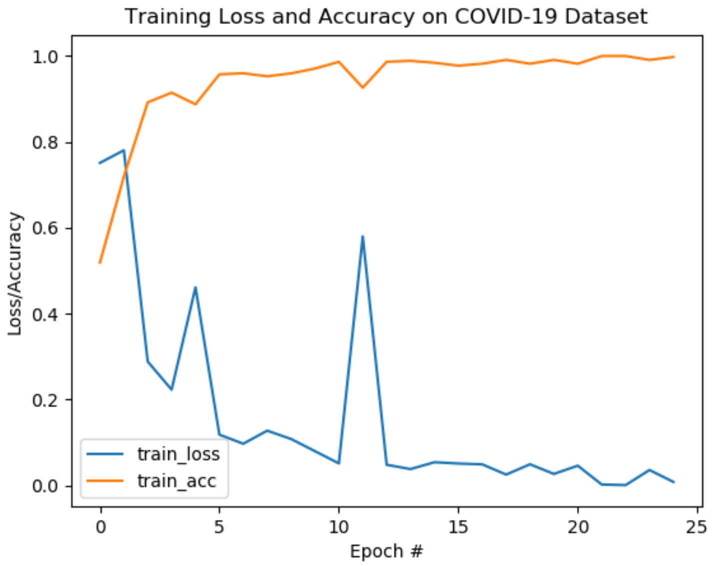

Figure2: Accuracy Vs Epochs curve using CNN on X-ray dataset

VGG is a convolutional neural network model proposed by Karen Simonyan& Andrew Zisserman of the University of Oxford as a conference paper at ICLR 2015. VGG16 advances the accuracy of ALEXNET by replacing large-sized kernels with grid sized kernels. It was trained on the ImageNet dataset for weeks and concluded on the accuracy of 92.7% of the top 5 test.

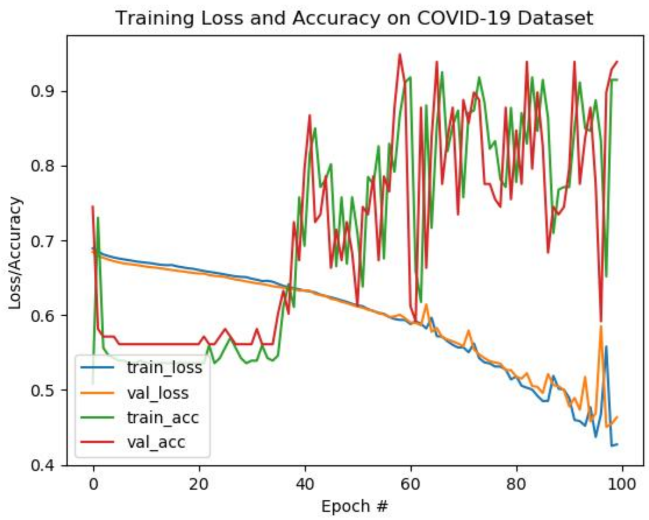

Figure3: - Accuracy Vs Epochs curve using LeNet5 on X-ray dataset

VGG has two variants as VGG16 and VGG19. VGG16 architecture contains 13 convolutional layers, 3 dense layers, and pooling layers. VGG19 architecture contains 16 convolutional layers, 3 dense layers, and pooling layers. Result of both are shown below in Figure4a and Figure4b. ResNet is a deep residual network that becomes the winner of ILSVRC 2015 in image classification, detection, and localization. ResNet50 contains 5 stages all together with convolution and identity blocks.

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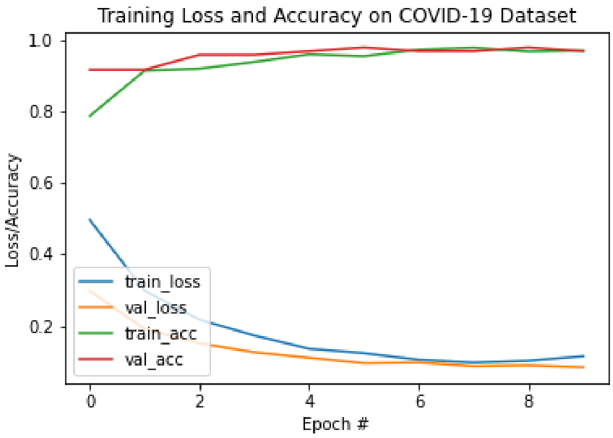

Figure4a: Accuracy Vs Epochs curve using VGG16 on X-ray dataset

ResNet uses skip connection i.e. output from an earlier layer to later layer, which helps in dealing with the vanishing gradient problem in neural nets. ResNet50 has been used by us for the classification task based on the x-ray image of covid19.

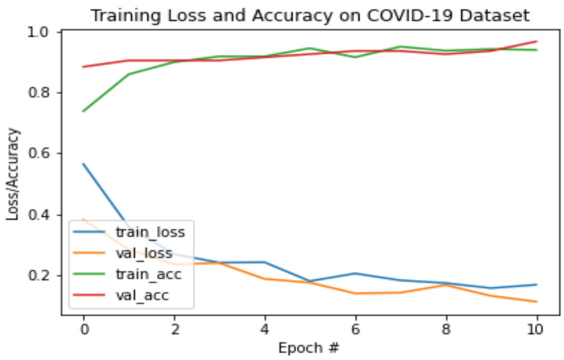

Figure4b:-: Accuracy Vs Epochs curve using VGG19 on X-ray dataset

Result of ResNet50 is seen in Figure5. DenseNets are the deep convolutional network that works in a feed-forward fashion. DenseNets has many advantages over other networks as- they alleviate the vanishing gradient problems, feature reuse, and propagation and reduces the parameter numbers.

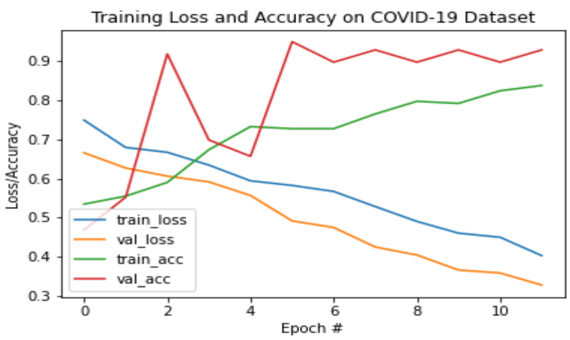

Figure5: -Accuracy Vs Epochs curve using ResNet50 on X-ray dataset

In DenseNets additional input from preceding layers is passed to the next layers as feature-maps. This technique is called concatenation (collective knowledge sharing from each layer). The numbers of channels are less than other network and the network is thinner. Thus making DenseNets as greater computational efficiency and memory efficiency. There are many variants of DenseNets as DenseNet121, DenseNet169, and DenseNet201 which are used by us on Covid19 detection. Result of these models is seen in Figure 6a & 6b & 6c.

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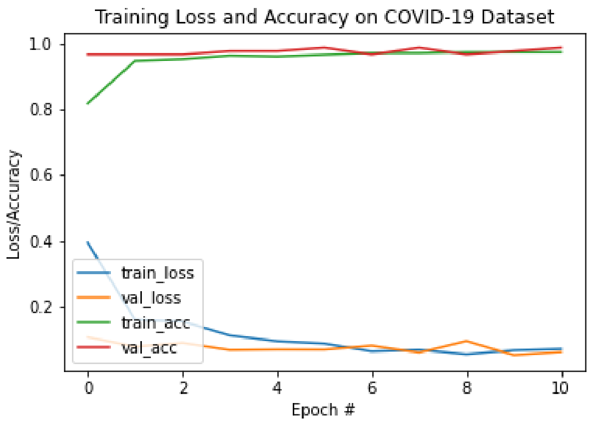

Figure6a: -Accuracy Vs Epochs curve using DenseNet121 on X-ray dataset

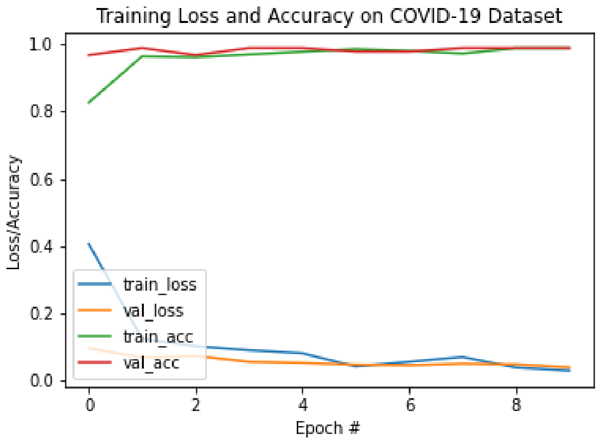

Figure6b: - Accuracy Vs Epochs curve using DenseNet169 on X-ray dataset

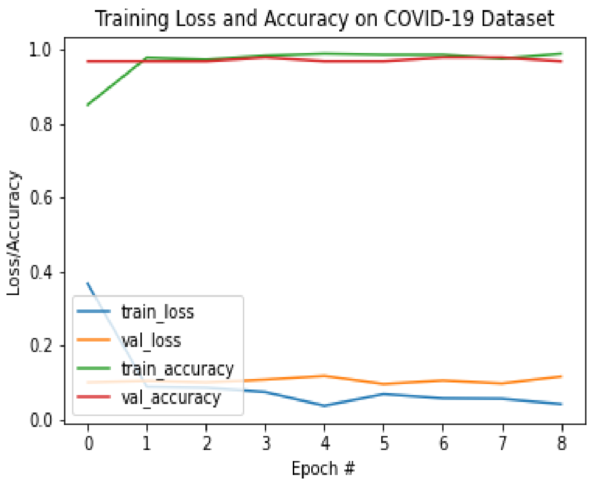

Figure6c: -Accuracy Vs Epochs curve using DenseNet201 on X-ray dataset

Neural Architecture Search Network (NASNet) is a search algorithm that searches for best architecture on a small dataset and transfers the block to a larger dataset. In NasNet, RNN controller is used as building blocks to create an end to end architecture. Schedules drop path is used by NasNet which helps in the generalization of the model. Normal cells and reduction cells are used in NasNet. NasNet takes 224 * 224 input image size. Two variants of NasNet are there which are used by us for further experimental classification. These are NasNetMobile and NasNetLarge. Result of them are seen in Figure 7a & 7b.

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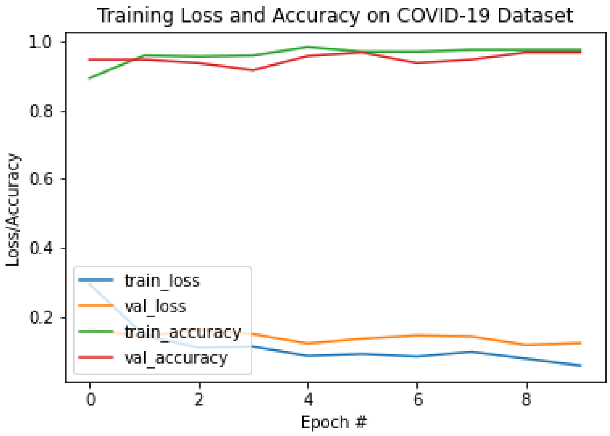

Figure7a: -Accuracy Vs Epochs curve using NasNetMobile on X-ray dataset

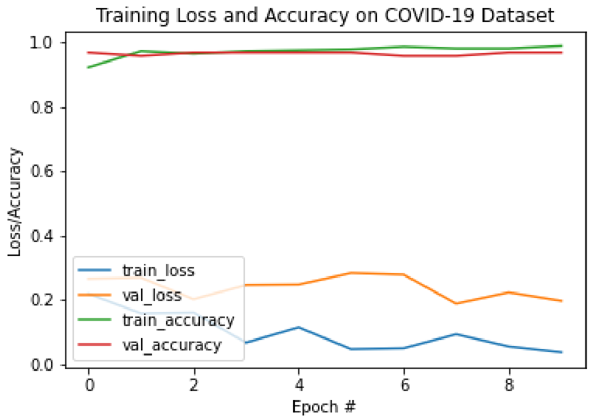

Figure7b: -Accuracy Vs Epochs curve using NasNetLarge on X-ray dataset

Inception deep convolutional architecture was introduced by GoogleNet which was much more complex than other networks. Further advancements were made in the Inception model network such as batch normalization and additional factorization ideas. This factorization aimed to reduce the no. Of parameters that are going to be used. For eg: - a 5*5 layer can be replaced by two 3*3 layers which result in a 28% decrease in the parameters from 25 to 18. Further factorization was applied to asymmetric convolutions which reduces more parameters. Inception v3 uses 42 layer deep convolutions which advance with: - RMSProp Optimizer, factorized 7*7 convolutions, BatchNorm in the auxiliary classifier and label smoothing concepts. Due to the good accuracy rate of the ResNet model a hybrid InceptionResnet model was also introduced that is similar to InceptionV4 functionality. We have used InceptionV3 and InceptionResnetV2 for our dataset as a classification algorithm. Result of these are seen in Figure 8a & 8b.

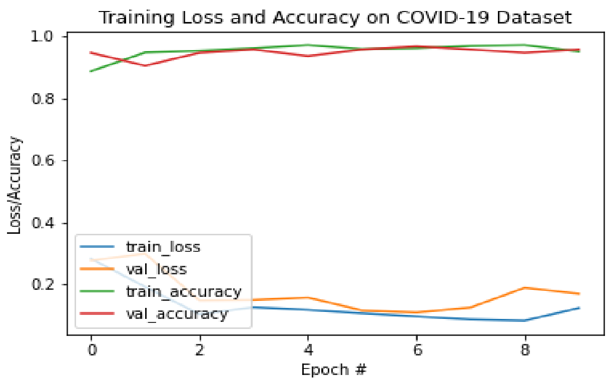

Figure8a: -Accuracy Vs Epochs curve using InceptionV3 on X-ray dataset

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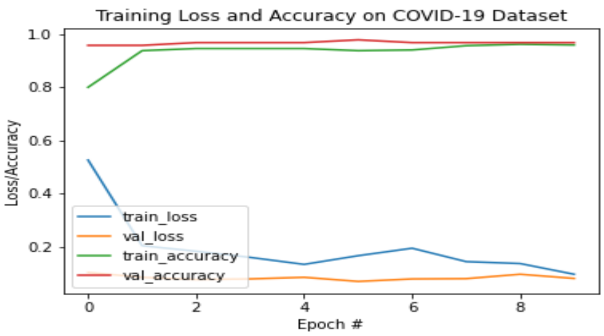

Figure8b: -Accuracy Vs Epochs curve using InceptionResnetv2 on X-ray dataset

MobileNet is an architecture which is suitable for mobile and embedded based application in the field of computer vision. The architecture of this network uses depth wise separable convolutions which further reduces the parameters being used. It comprises of a combination of depth wise convolution accompanied by pointwise convolution. These are a lightweight model that helps in the deployment of mobile devices easily. Result of Mobile Net used for our classification task is seen in Figure9.

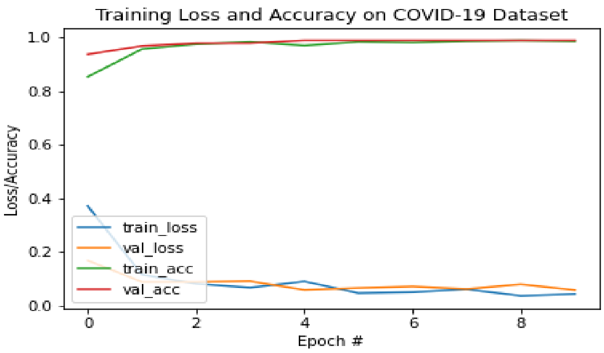

Figure9: -Accuracy Vs Epochs curve using MobileNetV2 on X-ray dataset

Xception is the extreme version of the Inception model which uses modified depth wise separable convolutional. Modified depth wise convolution here refers to the pointwise convolution at the initial stage and depth-wise at the next stage. The output of the pointwise convolution servers as the input for the depth wise convolutions in them. This modification was motivated by the InceptionV3 model which uses non-linearity after the first operation. But the Xception network doesn't use any intermediate RELU non-linearity. Result of Xception is used by us for the classification of the x-ray data are seen in Figure10.

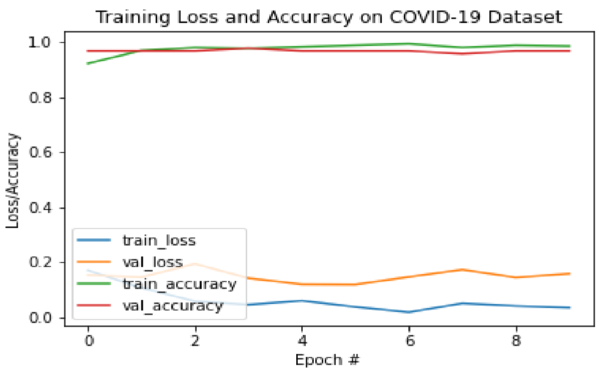

Figure10: -Accuracy Vs Epochs curve using Xception on X-ray dataset

We proposed a method to calculate the final output using the prediction of all these methods. This is done by using the majority rule at the end of the process i.e. COVID19 detection is positive when more than half of the architectures points in favour of it otherwise negative.

Table1: Comparative analysis of algorithms for COVID19 Detection

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Architectures used	Epochs	Training Loss	Training Accuracy	Validation Loss	Validation Accuracy	F1 Score
CNN	25	0.0083	0.9978	-	-	-
LeNet5	100	-	-	0.4272	0.9387	-
VGG16	10	0.1157	0.9705	0.0847	0.9688	0.97
VGG19	11	0.1672	0.9410	0.1116	0.9688	0.97
ResNet50	12	0.4035	0.8365	0.3287	0.9271	0.93
DenseNet121	11	0.0699	0.9759	0.0601	0.9896	0.99
DenseNet169	10	0.0287	0.9893	0.0386	0.9896	0.99
DenseNet201	9	0.0423	0.9893	0.1173	0.9688	0.97
MobileNetV2	10	0.0420	0.98866	0.0568	0.9896	0.99
NasNetMobile	10	0.0574	0.9759	0.1228	0.9688	0.97
NasNetLarge	10	0.0374	0.9893	0.1974	0.9688	0.97
InceptionV3	10	0.1250	0.9517	0.1712	0.9583	0.96
InceptionResnetV2	10	0.0970	0.9598	0.0814	0.9688	0.97
Xception	10	0.0351	0.9866	0.1581	0.9688	0.97

The Table1 records the performance of various Deep Learning Architectures over model performance metrics on COVID19 x-ray dataset. The epochs were tuned in a way to obtain the best model performance (Accuracy). The best performing architectures were decided on F1 score. The top three performers were DenseNet121, DenseNet169 and MobileNetV2 with F1 score of 0.99 each. Other architectures also gave comparable performance.

CONCLUSION AND FUTURE WORK

Overall, results obtained demonstrate a strong effect of deep learning architectures on the COVID19 x-ray datasets. We also discussed recently available datasets around the globe and the application of various DL architectures. LeNet5, CNN, Dense-Net121, DenseNet169, DenseNet201, ResNet50, VGG16, VGG19, MobileNetV2, NasNetMobile, NasNetLarge, InceptionV3, InceptionResnetv2 and Xception were presented with performance measures as a proof of concept. Further, we proposed a method to detect the COVID-19 presence based on the results of the above architectures. X-ray diagnosing can be used as an initial method during large population testing and can be made easily available at any remote place with good internet connection. Future studies can include adding more data but not limited to x-ray images. Moreover, COVID-19 diagnosing

with sonography (lung ultrasound) combined with radiography can be used to increase the detection power as ultrasound frequency analysis using acoustic models would be good enough in identifying COVID-19 presence.

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