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Review

Comparing Different Deep Learning Neural Networks in The Diagnosis of Covid-19

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Abstract:

Background: Covid-19 has been one of the most challenging pandemics facing the whole world. It has impacted lots of industries and affected the lives of millions of people so far. Due to this huge impact, various healthcare organizations have tried all the efforts to obtain a highly accurate, widely spread method for the diagnosis of Covid-19. Also, data scientists, machine learning and deep learning engineers have used all their skills – with the help of healthcare professionals of course– to aid in finding a suitable method for the diagnosis of Covid-19. Many deep learning models were developed with different accuracy, precision and f1 scores to aid in the process of diagnosing Covid-19.

Objective: The aim of this study is to review all the lately published literature to describe how the different deep learning models can be beneficial for the diagnosis of Covid-19.

Methods: A systematic review of the lately published literature from Google Scholar, PubMed, Nature journals, Springer and others by searching for related terminology such as (“Covid-19", diagnosis, chest, AI, deep learning). The scope of our search focused on the literature published in the year 2021 in order to analyze and review the latest findings these researches have to help battle this Covid-19 pandemic. The scope also focused on the published literature not including preprints or papers that weren’t peer reviewed in order to be considered as evidence based reliable research.

Results: 157 papers were totally found after the search, out of which there were 113 papers that were fitting our scope for this review. 111 papers discussed developing deep learning models that use chest X-ray images, CT scans or both to diagnose Covid-19 and differentiate its patients from healthy individuals. Only 2 papers contained deep learning models that used blood testing results to diagnose Covid-19.

Conclusions: Deep learning neural networks and techniques have contributed highly to solve real world problems in different fields and it is very obvious in the case of the Covid-19 pandemic how researchers have done immense hard work to fight this pandemic through developing highly efficient deep learning models that used either CNNs, random forests, SVM or ensemble learning techniques to get high accuracy, precision, f1 scores and recall rate scores which reflects how all these models with their different approaches can significantly contribute to successfully diagnosing patients with Covid-19 from healthy individuals.

Keywords: AI, “Covid-19", chest, deep learning, diagnosis

Background:

Since the outbreak of the novel corona virus SARS-CoV-2 or known as Covid-19, There has been more than 163 million confirmed cases by the World Health Organization globally, more than 3 million deaths until the date of this review (“WHO Coronavirus (COVID-19) Dashboard”, World Health Organization, accessed May 25,2021, https://covid19.who.int/). This pandemic has impacted the lives of people globally through many fields for example financially, socially, economically and of course medically. It is expected that around 690 million people are malnourished due to this crisis. Financially speaking, the time of lockdown specially has made it harder for daily based workers to earn the needed income to satisfy their needs and their families' needs. ("Impact of COVID-19 on people's livelihoods, their health and our food systems", World Health Organization, accessed May 25, 2021, https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people's-livelihoods-their-health-and-our-food-systems).

This has given rise to the powerful help that digital technologies such as Artificial Intelligence (AI) and deep learning models can offer to diagnose Covid-19 (Ting, D. S. W., Carin, L., Dzau, V., et al. 2020). AI has always been a very promising and powerful field that can aid people in their lives in different fields. It is very obvious how this field has advanced in the past couple of years and how many applications it has in the real world. This is of course fueled by the era of big data that we live in right now. These huge amounts of data in different fields can give our AI techniques and deep learning models a great input to grow experience that might be at some times greater than the human experience itself. All of this of course is very beneficial in the time of this pandemic. One of the applications for example is we can use the exponential ability of the different AI techniques to build huge experience in the field of radiology for example much faster than humans build their experience in the same field to help in diagnosing Covid-19 and thus fighting it (Hussain, A. A., Bouachir, O., Al-Turjman, F., et al. 2020)

<u>Materials and Methods:</u>

A search was performed on Google Scholar using the keywords mentioned above like Covid-19, chest, deep learning and others. The main focus of this search is reviewing the latest literature published in this year 2021 to add on all the efforts done by other researchers to be able to fight this pandemic. This resulted in a total of 157 papers. 104 papers were full text papers. The scope here is to review the latest papers related to applying various AI technologies to effectively diagnose Covid-19, thus all papers that were out of this scope were excluded either through being found out of the time range previously specified, being preprints or not peer reviewed or even being not found on the journal's main site. In this review, 113 papers were found to match this previously mentioned scope while 44 papers were out of scope. A systematic review was done for those papers and it was found that most papers discussed developing deep learning models mainly through CNN (Convolutional Neural Networks) that were trained and tested on either CXR (Chest X-ray) images or CT scans and finally measured to get insights on the performance of these models.

In the upcoming table a part of the analysis of the 157 papers with their main specifications is shown as follows:

Full Text	**Part of Text**	**Within Scope**	**Out of Scope**	**X-Ray**	**CT scan**	**Citation**
X		X		X	X	Elpeltagy, M. et al
X		X		X		Puente, A. L. C.et al
X		X		X		Almalki, Y. E. et al
			X (No peer review)			Ye, Q., Xia. et al
X		X		X	X	Shi, W. et al
X		X		X		Pandey, R. et al
X		X		X	X	Poly, T. N. et al
X		X		X		Luo, G.
X		X		X	X	Sharma, S., & Tiwari, S.
X		X			X	Yao, J. C. et al
			X (No enough data)			Roberts, M. AI
X		X		X		Elakkiya, R. et al
X		X		X		El-Kenawy, E. S. M. et al
	X	X		X		Naim Mursalim, M. K. et al
X		X			X	Tan, W. et al
X		X		X		Sharifrazi, D. et al
	X	X		X		Agarwal, C.. et al
	X	X		X		Samala, R. K. et al
	X	X			X	Sagie, N. et al
X		X		X		Elzeki, O. M.. et al
	X	X			X	Xie, Y.. et al
			X	Blood test screening		Mehralian, S. et al
X		X			X	Zhu, Z. et al
X		X		X		Jin, W. et al

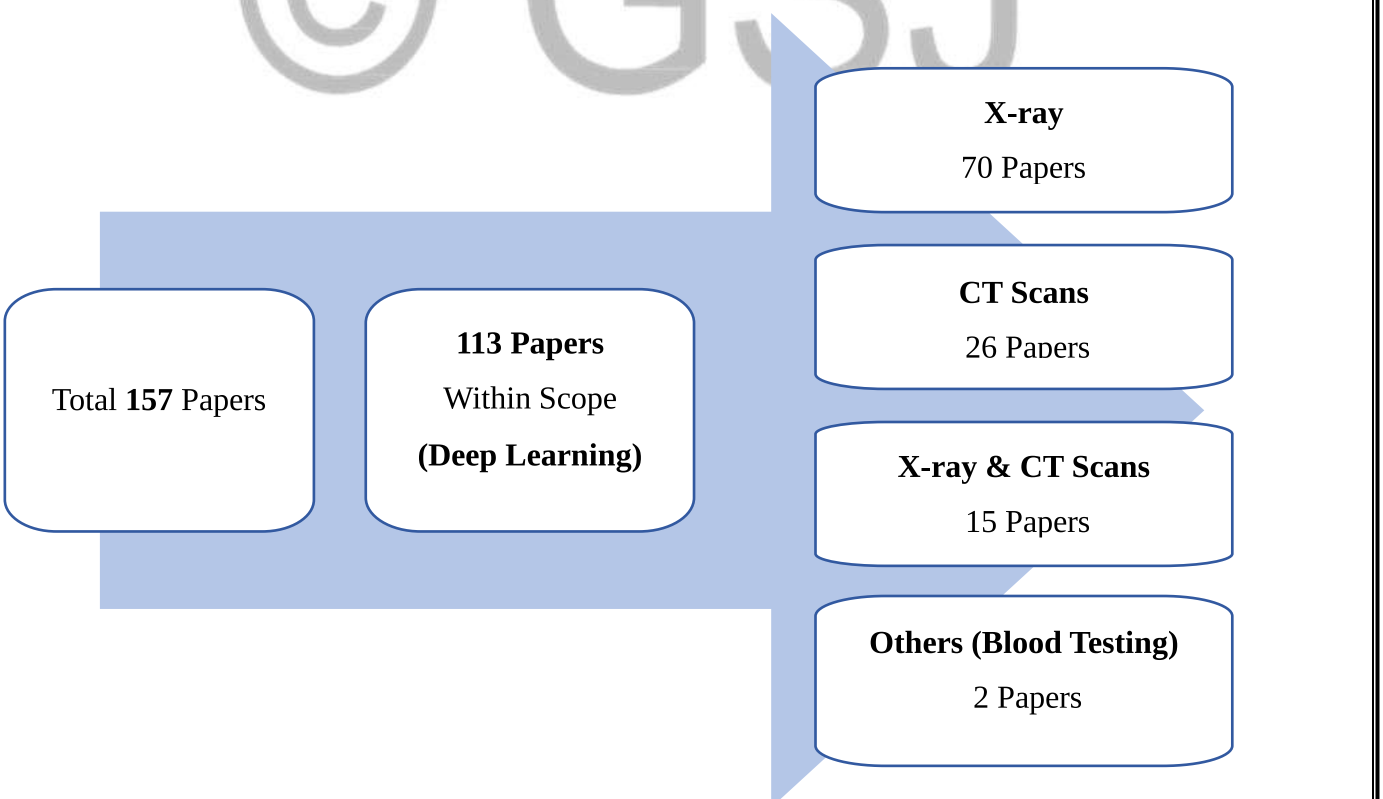
X		X		X	X	Kumbhakarna, V. M. et al
X		X		X	X	Mallio, C. A. et al
X		X		X		Kandhari, R. et al
X		X		X		Alghamdi, H. et al
			X	Blood test screening		Weeks, S.
X		X		X		Afifi, A. et al
X		X		X		Nair, R. et al
X		X			X	Modegh, R. G. et al
X		X		X		Xia, Y. et al
X		X			X	Santos, D. et al
X		X		X		Al-Falluji, R. A. et al
X		X			X	Mahmud, T. et al
	X	X		X		Shankar, K., & Perumal, E.
			X (No peer review)			Ravi, S. et al
X		X		X		Fontanellaz, M.. et al
X		X		X	X	Siddiqui, S. Y. et al
X		X		X		Paima, S. S. et al
X		X			X	Abdar, A. K. et al
X		X			X	Hasanzadeh, N.. et al
			X (No peer review)			Ghavami, R. et al
X		X		X		Cortés, E., & Sánchez, S.
X		X			X	Yener, F. M., & Oktay, A. B.
X		X		X		Ahmed, I. et al
X		X		X		Lucas, M. et al
X		X		X		Bekhet, S. et al
			X (No peer review)			Amran, D.. et al
X		X		X		Tammina, S.
X		X		X		Haritha, D. et al
X		X		X		Pelaez, E., & Loayza, F.
			X			Ancochea, J. et al
			X (Preprint)			Mosavi, A. et al
X		X		X		Vasal, S. et al
			X			Channa, A., & Popescu, N.

X		X		X		Carlile, M. et al
			X (No peer review)			Aviles-Rivero, A. I. et al

Table (1). High level information of some papers

<u>Results:</u>

113 papers resulted from our deep search where all of them contain deep learning models to diagnose Covid-19 through image classification neural networks. Most of the papers focused on using trained models such as convolutional neural networks (CNN) to diagnose Covid-19 (Sharma, S., & Tiwari, S. 2021; Sanghavi, F., Panetta, K., and Agaian, S. 2021; Gunasekaran, S., Rajan, S., Moses, L., et al 2021; Naim Mursalim, M. K., and Kurniawan, A. 2021). 111 papers discussed using models to differentiate between X-rays of patients with Covid-19 and healthy people or using CT scans instead or some papers discussed both approaches. 70 papers used X-ray images to train the deep learning models (Sharma, S., & Tiwari, S. 2021; Gunasekaran, S., Rajan, S., Moses, L., et al 2021). 26 papers used CT scan images (Sanghavi, F., Panetta, K., and Agaian, S. 2021; Yao, J. C., Wang, T., Hou, G. H., et al. 2021; Mahmud, T., Rahman, M. A., Fattah, S. A. A., et al. 2021), while



15 papers only compared between using both. It was found that only 2 papers discussed using deep learning models and neural networks to diagnose Covid-19 through the blood tests of patients and others of healthy individuals (Mehralian, S., Jalaeian Zaferani, E., Shashaani, S., et al. 2021; Weeks, S. 2021). All of this is shown in Fig (1).

Fig (1). Results of the literature review process

Discussion:

Neural Networks of Covid-19:

An important question might arise here is which neural network is best to use in cases of medical imaging and what the differences between all neural networks are. One significant comparison was done by (Trivedi, N. K., Simaiya, S., Lilhore, U. K., et al. 2021) where it compares between the use of CNNs or the use of other neural networks like random forests or SVMs (support vector machines) and so on. The following was found (Trivedi, N. K., Simaiya, S., Lilhore, U. K., et al. 2021):

Model	Dataset	Number of Patients	Validation Framework	Data set Description	Outcomes
Convolutional Neural Network	Clinical scientific COVID-19 data	5000 COVID patient data	Validation using Holdout	COVID-19 clinical CT images including the patient with infectious as well as unusual disease	Precision and Specificity more than 90%[13,14]
Machine Learning based SVM Classification	Clinical scientific COVID-19 data	800 COVID patient data	Validation using Holdout	COVID infected patients, including critical & non-serious cases. Also includes data for patients diabetics and coronary	Precision and Specificity more than 75 %, with training & testing set[15,16]
CNN based COVID Net model	Clinical scientific COVID-19 data	650 Patient data	Rotation estimation based Cross-validation	Different x-ray images of COVID patients Male, Female	Precision more than 90% for Binary classes and Multi-classes achieves 88%[7,18]
Random forest Machine learning method	Clinical scientific COVID-19 data	2500 COVID patient data	Rotation estimation based Cross-validation	different BLOOD sample of COVID patients collected from various source	Accuracy and Specificity more than 93%[19,20]

Table (2). Comparison of the various ML & DL method throughout the research of COVID-19 (Trivedi, N. K., Simaiya, S., Lilhore, U. K., et al. 2021**)**

As seen here this table shows how efficient are the CNNs in working with either CT scan images or X-rays or even blood test samples. Their outcomes are usually high precision and accuracy percentages (not less than 90%) which eventually results in high f1 scores as well.

Also, (Elpeltagy, M., and Sallam, H. 2021) recommend using CNNs because they are much more reliable than other modelling techniques and that is due to the fact that CNNs have much better feature extraction process where they are extracted from multiple layers and thus give more specified features at the end of the neural network (Sanghavi, F., Panetta, K., and Agaian, S. 2021). This can be clearly observed when reviewing other papers where researchers tend to use CNNs more often than other modelling techniques (Sanghavi, F., Panetta, K., and Agaian, S. 2021; Trivedi, N. K., Simaiya, S., Lilhore, U. K., et al. 2021; Sharma, S., & Tiwari, S. 2021; Kumar, S. 2021). CNNs ready to use models are many like ResNet50, GoogleNet, AlexNet and of course DenseNet201. In this paper, (Elpeltagy, M., and Sallam, H. 2021) worked on modifying one of these readymade CNNs which was ResNet50 by adding 3 layers which gave the model higher accuracy percentages in identifying either CT scans or chest X-rays (around 97%) which is a very effective percentage compared to the other well-known models mentioned above (Sanghavi, F., Panetta, K., and Agaian, S. 2021).

Fig (2). The ResNet50 model architecture before and after modifications (Elpeltagy, M., and Sallam, H. 2021**).**

Another interesting paper was the work of (Sharifrazi, D., Alizadehsani, R., Roshanzamir, M. et al 2021) which combined the use of CNNs, SVM and Sober filter to achieve a model outcome with almost the highest accuracy, sensitivity and specificity scores which are 99.02%, 100% and

95.23%.This gives great insight on the idea of combining multiple neural networks to obtain exceptional modelling outcomes.

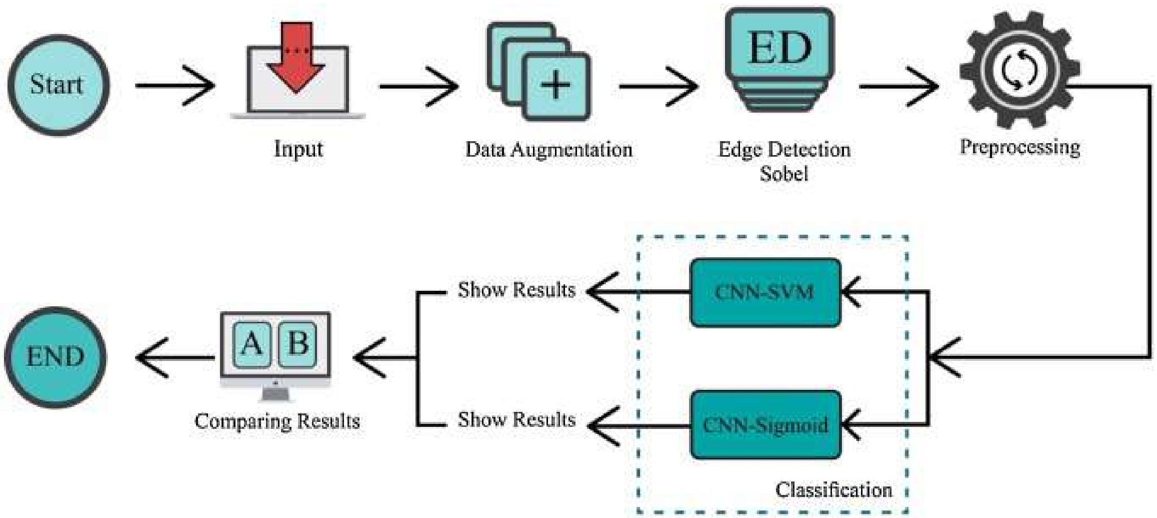


Fig (3). Proposed methodology used for the automated detection of COVID-19 patients using X-ray images (Sharifrazi, D., Alizadehsani, R., Roshanzamir, M. et al 2021**)**

Now let us look at (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021) paper where they proposed a huge model that for the first time combine the concepts of transfer learning and stacking in the same model .First of all, Phase1 which as the transfer learning phase that started with data collection of chest X-rays for healthy and non-healthy individuals either pneumonia patients or Covid-19 patients, then these X-ray images were augmented. These augmented images were used through transfer learning techniques to undergo feature extraction through feature maps. Then, it is time for the baseline CNN step where these images are fed into different CNNs for training and classification which then result in the following outcomes. The result is either the image refers to a healthy individual or a patient in general. If a patient was identified then the image is classified as a pneumonia X-ray image or Covid-19 X-ray image. Here comes the end of Phase 1: Transfer learning phase.

Phase 2 is the stacking phase or known as ensemble learning. It starts with selecting the best performing CNN models from the previous phase according to their performance metrics such as accuracy scores, precision scores and f1 scores. The chosen models are then fed by the input X-ray images and every model gives its outcome. Here comes the interesting part where all outcomes of each model – which are all known as meta learners - are combined to give a final output of either a healthy individual a Covid-19 patient or a pneumonia patient. Here ends Phase 2 ensemble learning. This is the Covid Screenet proposed by (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021) which is shown as follows:

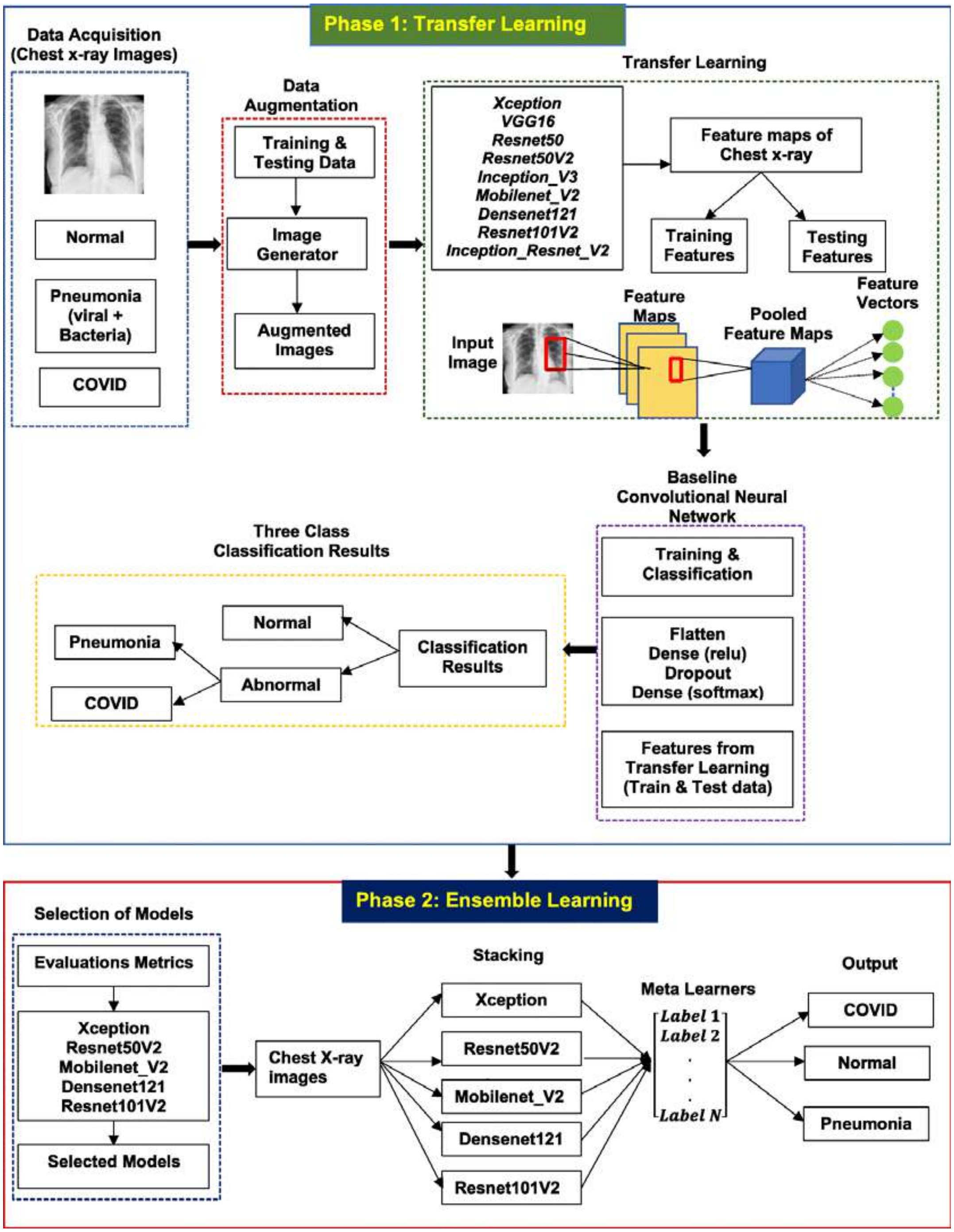


Fig (4). Bifold architectural framework of COVID_SCREENET (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021**)**

5 models were chosen after running this process which are Xception, Resnet50, Mobilenet_V2, Densenet121 and Resnet101V2. These models showed significantly high accuracy scores which are 99.7%, 96.9%, 98.1%, 97.8% and 97% respectively (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021). This shows how the concept of combining transfer learning with ensemble learning was a state-of-the-art concept and gave very promising outcomes. Not only the accuracy scores were statistically significant but also the precision and recall scores for the new version of the Resnet50 in case of Covid-19 is 100% which indicates very high sensitivity and specificity if compared to the original Resnet50 that had scores around 95%.

Deep learning for Blood testing results:

There hasn't been much research papers published focusing on using deep learning techniques to identify Covid-19 patients from healthy individuals using the blood testing results (Mehralian, S., Jalaeian Zaferani, E., Shashaani, S., et al. 2021; Weeks, S. 2021). (Mehralian, S., Jalaeian Zaferani, E., Shashaani, S., et al. 2021) for example worked on 3 algorithms and could get an outcome of 84% accuracy and 83% f1 score. This model is now being used already through CODAS. The other paper (Weeks, S. 2021) developed another model with an accuracy of 86% in the community. It can be seen that the outcomes of these models have moderately significant accuracy scores but not as significant as using CNNs for example for the diagnosis of Covid-19.

Transfer Learning in Covid-19 crisis:

It is worth mentioning that without the concept of transfer learning we wouldn't have been able to run all this research on Covid-19 chest X-rays or CT scans to be able to find a way for an efficient an accurate diagnosis process. The concept is exceptionally significant in this crisis due to our urgent need to find a rapid and effective solution which is facilitated through retraining deep complicated neural networks with small number of images to obtain significant outcomes (KADIR, M. A., MAHBUB, Z. B., & ISLAM, K. 2020)

Data Augmentation in Covid-19 crisis:

Due to the exceptional situation of Covid-19, the X-ray or CT scan images available are biased towards the Covid-19 patients which is a challenge that faces deep learning developers. This was overcomed by (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021) for example in their work through data augmentation techniques which help rebalance the input data. It is also very useful in cases where we have a small number of images in general to feed our models. This can be obvious through the chart here for example in the same previously mentioned paper (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021).

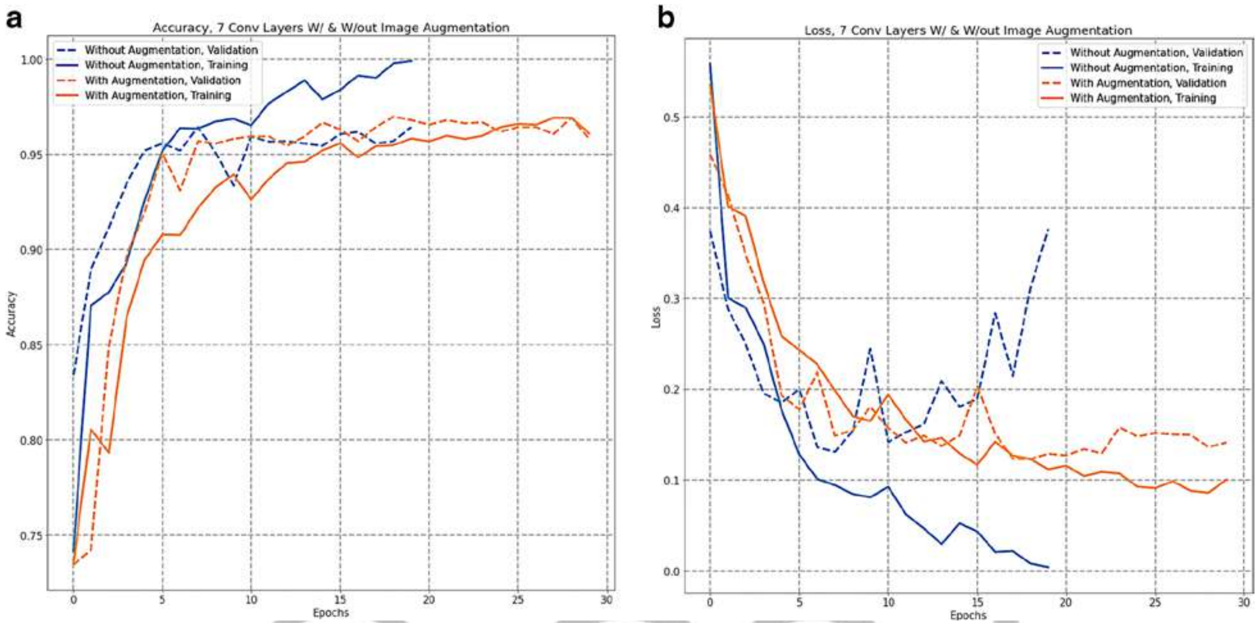


Fig (5). Resnet50 with and without augmentation (<u>a</u>) Accuracy and (<u>b</u>) Loss (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021**)**

<u>Limitations:</u>

In a time of a serious crisis like the Covid-19 pandemic and working with deep learning models, it is very hard to obtain balanced number of input images of either chest X-rays or CT scans. This is because most of the time people who have symptoms are the ones that go to the physicians and undergo CT scans or any sort of radiographic imaging to aid the diagnosis, thus collecting X-ray images from healthy individuals specially in a time of a highly infectious pandemic is a real challenge. This was handled in a way by deep learning researchers through undergoing image augmentation techniques to try and balance the number of images in order to train the models.

Another limitation here is the fact that this is an emergency time where every research is needed to help battle the pandemic and as we have seen above there were many preprints and papers that weren't peer reviewed and we had to skip them from this review but they may have contained very beneficial information and modelling concepts that could aid with diagnosing Covid-19.

Conclusions:

It is with no doubt that the work done by different deep learning engineers is impressive and has positively impacted the diagnosis process of Covid-19 patients. Many deep learning models have statistically significant accuracy scores, precision scores and f1 scores. It was shown how some models used the concepts of transfer learning and tended to use CNNs along with data augmentation techniques in order to get high scores and highly efficient models. Other researchers tended to combine multiple approaches like the work done by (Elakkiya, R., Vijayakumar, P. and Karuppiah, M. 2021) which combined the transfer learning approach with the ensemble learning approach and thus were able to efficiently identify healthy individuals from Covid-19 patients from pneumonia patients. Here it is very important to highlight the vital impact that these different approaches can do to significantly help with the process of diagnosing Covid-19 during this pandemic. The next step is to advance with the results and scores reached through research so far and try to find new state-of-the-art solutions. It is also the role of the different healthcare organizations to start significantly implementing these models in their diagnosis process because this can offer great help to control and eventually end this pandemic.

Conflicts of Interest:

The authors declare no conflict of interest

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The authors declare there wasn't any funding

Contributions:

The authors contributed equally to this review

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Figures' index:

Tables' index: