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A Novel Approach for Early Detection of Covid-19 using Hybrid Transfer Learning Method using Chest X-ray Images

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ABSTRACT: Novel coronavirus pneumonia (COVID-19) is a contagious disease that has already caused thousands of deaths and infected millions of people worldwide. Thus, all technological gadgets that allow the fast detection of COVID-19 infection with high accuracy can offer help to healthcare professionals. This study is proposed to detect COVID-19 based on chest X-ray imaging. In this work, we have proposed an automatic prediction of COVID-19 using a deep convolution neural network based pre-trained transfer models and chest X-ray images. For this purpose, we have used ConvNet, AlexNet and DenseNet pre-trained models to obtain higher prediction accuracies for different X-ray images of normal (healthy) and COVID-19 patients. The classification method uses transfer learning method for the purpose of optimizing hyper-parameter values within the transfer learning tuning of a CNN. The trained model is then used to classify a set of X-ray images, upon which the qualitative explanations are performed. The presented approach was tested on a collection of 116 COVID and 317 normal X-ray images to achieve high classification accuracy i.e., 92%. The achieved high classification accuracy enabled us to perform a qualitative in-depth analysis, which revealed that there are some regions of greater importance when identifying COVID19 cases.

KEYWORDS: Covid-19, Transfer Learning method, X-ray.

I. INTRODUCTION

Since December 2019, when in Wuhan city, the capital of Hubei province in China, the cases of "unknown viral pneumonia" started to gather, the world is witnessing a huge spread of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Based on the World Health Organization report published on the 15th of April 2020, there were 1.9 million confirmed cases and 123,010 deaths globally, spreading across 210 countries and territories [1] The COVID-19 is the seventh known coronavirus to infect humans. The two also known examples of coronavirus include severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) [2]

At this early stage in the COVID-19 epidemic, researchers are looking for all possible insights into the new corona virus SARS-CoV-2. One of the possibilities is an in-depth analysis of X-ray images from COVID-19 patients. We first developed a new adapted classification method that is able to identify COVID19 patients based on a chest X-ray, and then adopted a local interpretable model-agnostic explanations approach to provide the insights. The classification method uses a grey wolf optimizer algorithm for the purpose of optimizing hyper-parameter values within the transfer learning tuning of a CNN.

With the advancements of deep learning methods and techniques in recent years, especially the ones utilizing convolutional neural networks (CNNs), various research works proved that the application of such methods against the

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medical domain problems is resulting in encouraging results [4]. Especially in the last months there is an increase of research focused on applying the machine learning algorithms to identification of COVID-19. One of most common approaches to tackle the mentioned issue is to utilize the transfer learning approach as presented in [5], [6]. Based on our previous experience with the detection of brain hemorrage from head CT images [7] as well as promising results from similar studies, we set our goals to adapting the method to identify a COVID-19 chest X-ray images from a relatively small dataset. Beside providing and evaluating a predictive model, we also conducted an analysis of interpretable representations of our model in order to gain useful insights on how the model perceives the chest X-ray images, evaluating the model's decisions from a qualitative perspective.

X-ray is an imaging technique that is used to investigate fractures, bone displacement, pneumonia, and tumor. X-rays have been used for many decades and provide an astonishingly fast way of seeing the lungs and, therefore, can be a helpful tool in the detection of COVID-19 infections [8], [9]. They are capable of generating images that show lung damage, such as from pneumonia caused by the SARS-CoV-2 virus [10]. Since X-rays are very fast and cheap, they can help to triage patients in places where the healthcare system has collapsed or in places that are far from major centers with access to more complex technologies. Furthermore, there are portable X-ray devices that can be easily transported to where it is needed [10]. CT scans make use of the principles of X-ray in an advanced manner to examine the soft structures of the body. It is also used to obtain clearer images of organs and soft tissues [11]. On the other hand, X-rays use less radiation [12], thus using an X-ray is faster, less harmful, and presents lower cost than a CT scan. Narin et al. [8] proposed an automatic detection of COVID-19 using chest X-rays and CNNs. Apostolopoulos et al. [9] also proposed the automatic detection of the disease but analyzing three classes: COVID-19, common pneumonia, and normal conditions.

Since mid February 2020, various researchers [3] started to collect and publish anonymized X-ray chest images of patients diagnosed with COVID-19, which let the researchers to study the collected data and possibly identify useful patterns, which could give us useful insights and enable us to design and develop computer-aided diagnosis systems which could facilitate work for radiologists.

In this study, we have proposed an automatic prediction of COVID-19 using a deep convolution neural network based pre-trained transfer models and chest X-ray images. For this purpose, we have used ConvNet, AlexNet and DenseNet pre-trained models to obtain higher prediction accuracies for different X-ray images of normal (healthy) and COVID-19 patients.

II. LITERATURE SURVEY

Islam et al., [13] aimed to overview the recently developed systems based on deep learning techniques using different medical imaging modalities like Computer Tomography (CT) and X-ray. This review specifically discusses the systems developed for COVID-19 diagnosis using deep learning techniques and provides insights on well-known data sets used to train these networks. It also highlights the data partitioning techniques and various performance measures developed by researchers in this field. Taxonomy is drawn to categorize the recent works for proper insight. Finally, they have concluded by addressing the challenges associated with the use of deep learning methods for COVID-19 detection and probable future trends in this research area. This is intended to provide experts (medical or otherwise) and technicians with new insights into the ways deep learning techniques are used in this regard and how they potentially further works in combatting the outbreak of COVID-19.

Hussain et al., [14] summarized the current state of AI applications in clinical administrations while battling COVID-19. Furthermore, they highlight the application of Big Data while understanding this virus. They have also overview various intelligence techniques and methods that can be applied on various types of medical information-based pandemic. They classify the existing AI techniques in clinical data analysis, including neural systems, classical SVM, and edge significant learning. Also, an emphasis has been made on regions that utilize AI-oriented cloud computing in combating various similar viruses to COVID-19. This survey study is an attempt to benefit medical practitioners and medical researchers in overpowering their faced difficulties while handling COVID-19 big data. The investigated

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techniques put forth advances in medical data analysis with an exactness of up to 90%. They further end up with a detailed discussion about how AI implementation can be a huge advantage in combating various similar viruses.

Jamshidi et al., [15] rendered a response to combat the virus through Artificial Intelligence (AI). Some Deep Learning (DL) methods have been illustrated to reach this goal, including Generative Adversarial Networks (GANs), Extreme Learning Machine (ELM), and Long /Short Term Memory (LSTM). It delineates an integrated bioinformatics approach in which different aspects of information from a continuum of structured and unstructured data sources are put together to form the user-friendly platforms for physicians and researchers. The main advantage of these AI-based platforms is to accelerate the process of diagnosis and treatment of the COVID-19 disease. The most recent related publications and medical reports were investigated with the purpose of choosing inputs and targets of the network that could facilitate reaching a reliable Artificial Neural Network-based tool for challenges associated with COVID-19. Furthermore, there are some specific inputs for each platform, including various forms of the data, such as clinical data and medical imaging which can improve the performance of the introduced approaches toward the best responses in practical applications.

Vrbancic et al., [16] developed a new adapted classification method that is able to identify COVID19 patients based on a chest X-ray, and then adopted a local interpretable model-agnostic explanations approach to provide the insights. The classification method uses a grey wolf optimizer algorithm for the purpose of optimizing hyper-parameter values within the transfer learning tuning of a CNN. The trained model is then used to classify a set of X-ray images, upon which the qualitative explanations are performed. The presented approach was tested on a dataset of 842 X-ray images, with the overall accuracy of 94.76%, outperforming both conventional CNN method as well as the compared baseline transfer learning method. The achieved high classification accuracy enabled us to perform a qualitative in-depth analysis, which revealed that there are some regions of greater importance when identifying COVID19 cases, like aortic arch or carina and right main bronchus. The proposed classification method proved to be very competitive, enabling one to perform an in-depth analysis, necessary to gain qualitative insights into the characteristics of COVID-19 disease.

Wang et al., [17] developed a deep learning-based model for automatic COVID-19 diagnosis on chest CT which is helpful to counter the outbreak of SARS-CoV-2. A weaklysupervised deep learning framework was developed using 3D CT volumes for COVID-19 classification and lesion localization. For each patient, the lung region was segmented using a pre-trained UNet; then the segmented 3D lung region was fed into a 3D deep neural network to predict the probability of COVID-19 infectious; the COVID-19 lesions are localized by combining the activation regions in the classification network and the unsupervised connected components. 499 CT volumes were used for training and 131 CT volumes were used for testing. Our algorithm obtained 0.959 ROC AUC and 0.976 PR AUC. When using a probability threshold of 0.5 to classify COVID-positive and COVID-negative, the algorithm obtained an accuracy of 0.901, a positive predictive value of 0.840 and a very high negative predictive value of 0.982. The algorithm took only 1.93 seconds to process a single patient's CT volume using a dedicated GPU. Weakly-supervised deep learning model can accurately predict the COVID-19 infectious probability and discover lesion regions in chest CT without the need for annotating the lesions for training. The easily-trained and high-performance deep learning algorithm provides a fast way to identify COVID-19 patients, which is beneficial to control the outbreak of SARS-CoV-2.

Zheng et al., [18] proposed a hybrid artificial-intelligence (AI) model for COVID-19 prediction. First, as traditional epidemic models treat all individuals with coronavirus as having the same infection rate, an improved susceptible–infected (ISI) model is proposed to estimate the variety of the infection rates for analyzing the transmission laws and development trend. Second, considering the effects of prevention and control measures and the increase of the public's prevention awareness, the natural language processing (NLP) module and the long short-term memory (LSTM) network are embedded into the ISI model to build the hybrid AI model for COVID-19 prediction. The experimental results on the epidemic data of several typical provinces and cities in China show that individuals with coronavirus have a higher infection rate within the third to eighth days after they were infected, which is more in line with the actual transmission laws of the epidemic. Moreover, compared with the traditional epidemic models, the proposed hybrid AI model can significantly reduce the errors of the prediction results and obtain the mean absolute percentage errors

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(MAPEs) with 0.52%, 0.38%, 0.05%, and 0.86% for the next six days in Wuhan, Beijing, Shanghai, and countrywide, respectively.

Wang et al., [19] hypothysed based on covid-19 radiographical changes in CT images that artificial intelligence's deep learning methods might be able to extract covid-19's specific graphical features and provide a clinical diagnosis ahead of pathogenic test, thus saving critical time for disease control.

Chen et al., [20] aimed to construct a system based on deep learning for detecting COVID-19 pneumonia on high resolution CT, relieve working pressure of radiologists and contribute to the control of the epidemic. The deep learning model showed a comparable performance with expert radiologist, and greatly improves the efficiency of radiologists in clinical practice. It holds great potential to relieve the pressure of frontline radiologists, improve early diagnosis, isolation and treatment, and thus contribute to the control of the epidemic.

Waheed et al., [21] presented a method to generate synthetic chest X-ray (CXR) images by developing an Auxiliary Classifier Generative Adversarial Network (ACGAN) based model called CovidGAN. In addition, they demonstrated that the synthetic images produced from CovidGAN can be utilized to enhance the performance of CNN for COVID-19 detection. Classification using CNN alone yielded 85% accuracy. By adding synthetic images produced by CovidGAN, the accuracy increased to 95%.

Butt et al., [22] reviewed a study that compared multiple convolutional neural network (CNN) models to classify CT samples with COVID-19, Influenza viral pneumonia, or no-infection. They have compared this mentioned study with one that is developed on existing 2D and 3D deeplearning models, combining them with the latest clinical understanding, and achieved an AUC of 0.996 (95%CI: 0.989–1.00) for Coronavirus vs Non-coronavirus cases per thoracic CTstudies. They calculated a sensitivity of 98.2%and a specificity of 92.2%.

Sethi et al., [23] reviewed that screening of large numbers of individuals is the need of the hour to curb the spread of disease in the community. Real - time PCR is a standard diagnostic tool being used for pathological testing. But the increasing number of false test results has opened the path for exploration of alternative testing tools. Chest X-Rays of COVID-19 patients have proved to be an important alternative indicator in COVID-19 screening. But again, accuracy depends upon radiological expertise. A diagnosis recommender system that can assist the doctor to examine the lung images of the patients will reduce the diagnostic burden of the doctor. Deep learning techniques specifically Convolutional Neural Networks (CNN) has proven successful in medical imaging classification. Four different deep CNN architectures were investigated on images of chest X-Rays for diagnosis of COVID-19. These models have been pre-trained on the ImageNet database thereby reducing the need for large training sets as they have pre-trained weights. It was observed that CNN based architectures have the potential for diagnosis of COVID-19 disease.

The COVID-19 is still an ongoing pandemic that is creating new records in terms of cumulative and daily numbers for global infection and death. Deep learning based automatic diagnosis of COVID-19 which provides consistent and accurate solutions, has played a significant role to assist with the diagnosis of this disease. Testing of large numbers of individuals is crucial to curb the spread of disease. Realtime PCR is a gold standard pathological test for the diagnosis of this disease. But the increasing number of negative false reporting has led to the use of Chest X-Rays as an alternative for diagnosis of COVID-19. Deep learningbased recommender systems can be of great help in this scenario when the volume of patients is very high and required radiological expertise is low. The introduced conceptual structures and platforms in the research field of AI-based techniques, which are suitable for dealing with COVID-19 issues, have been discussed. Different techniques have been developed, incorporating COVID-19's diagnostic systems, such as RNN, LSTM, GAN, and ELM. The geographical issues, high-risk people, and recognizing and radiology were the main problems with COVID-19 and have been studied and discussed.

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III. PROPOSED METHODOLOGY

In this study, we used COVID-19 chest X -ray images data set, viral pneumonia chest images, and healthy chest images, to evaluate the effectiveness of the state-of-the-art pre-trained Convolutional Neural Networks with regard to the automatic diagnosis of COVID-19 from chest X-rays. An automated detection of COVID-19 was proposed that applied pre-trained transfer models on Chest X-ray images based on a deep convolution neural network. A collection of of 116 COVID and 317 normal chest X-rays images are stored and used for training and evaluation of the CNNs to achieve such a purpose.

In the analysis of medical data, one of the biggest difficulties faced by researchers is the limited number of available datasets. Deep learning models often need a lot of data. Labeling this data by experts is both costly and time consuming. The biggest advantage of using transfer learning method is that it allows the training of data with fewer datasets and requires less calculation costs. With the transfer learning method, which is widely used in the field of deep learning, the information gained by the pre-trained model on a large dataset is transferred to the model to be trained.

In this study, we built deep CNN based ConvNet, AlexNet and DenseNet models for the classification of COVID-19 Chest X-ray images to predict COVID-19 patients. In addition, we applied transfer learning technique to overcome the insufficient data and training time. The schematic representation of conventional CNN including pre-trained ConvNet, AlexNet and DenseNet models for the prediction of normal (healthy), COVID-19 and pneumonia patients were depicted in Figure 1.

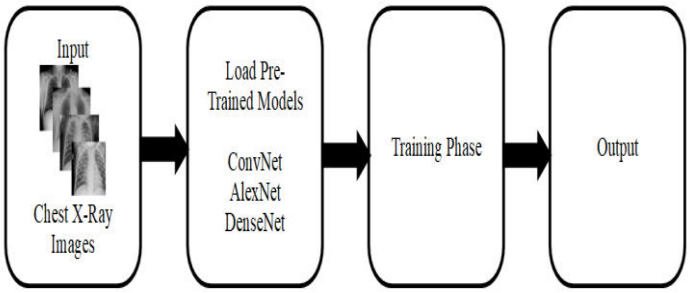

Figure 1: Proposed Architecture

Deep neural network (DNN) has a great capability in the image classification task [24] and convolutional neural network (CNN, or ConvNet) [25] is one of the most popular classes of DNN. AlexNet [26], DenseNet [27] are some of the popular convulational networks which were used to train on dataset in this work.

AlexNet [26] architecture is composed of five convolutional layers, followed by three fully connected layers. Instead of the standard tanh or sigmoid function, it uses ReLU (Rectified Linear Unit) for the non-linear part after each convolutional and fully connected layer. ReLU is much faster in case of training than the sigmoid function. It also solved the problem of over-fitting by introducing the idea of a drop-out layer.

DenseNet architecture is designed in such a way that all the layers are directly connected ensuring maximum information flow in the network. Also unlike other models, here features are concatenated. This architecture requires less parameters and computation to get state-of-art performace.

IV. RESULTS

This section contains results and discussion about the proposed denoising model in the detection of Covid-19 using CNN approach based transfer learning method.
Figure 2 shows front end design of Django framework.

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Figure 2: Front end Design of Django Framework

Representative of Chest X-Ray images of Normal and COVID patients are shown in Figure 3.

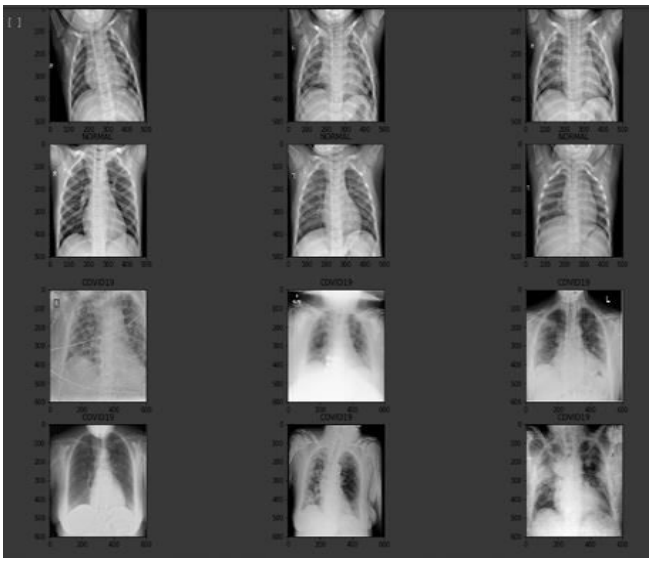

Figure 3 : Chest X-Ray Images

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conv5_block32_1_conv (Conv2D)	(None, 9, 9, 128)	208896	conv5_block32_0_relu[0][0]
conv5_block32_1_bn (BatchNormal	(None, 9, 9, 128)	512	conv5_block32_1_conv[0][0]
conv5_block32_1_relu (Activatio	(None, 9, 9, 128)	0	conv5_block32_1_bn[0][0]
conv5_block32_2_conv (Conv2D)	(None, 9, 9, 32)	36864	conv5_block32_1_relu[0][0]
conv5_block32_concat (Concatena	(None, 9, 9, 1664)	0	conv5_block31_concat[0][0] conv5_block32_2_conv[0][0]
bn (BatchNormalization)	(None, 9, 9, 1664)	6656	conv5_block32_concat[0][0]
relu (Activation)	(None, 9, 9, 1664)	0	bn[0][0]
flatten (Flatten)	(None, 134784)	0	relu[0][0]
dense (Dense)	(None, 512)	69009920	flatten[0][0]
dropout (Dropout)	(None, 512)	0	dense[0][0]
dense_1 (Dense)	(None, 256)	131328	dropout[0][0]
dense_2 (Dense)	(None, 128)	32896	dense_1[0][0]
dropout_1 (Dropout)	(None, 128)	0	dense_2[0][0]
dense_3 (Dense)	(None, 64)	8256	dropout_1[0][0]
dense_4 (Dense)	(None, 3)	195	dense_3[0][0]

Total params: 81,825,475
Trainable params: 69,182,595
Non-trainable params: 12,642,880

Figure 4: Traning the dataset using the ConvNet, AlexNet(relu) and DenseNet models.

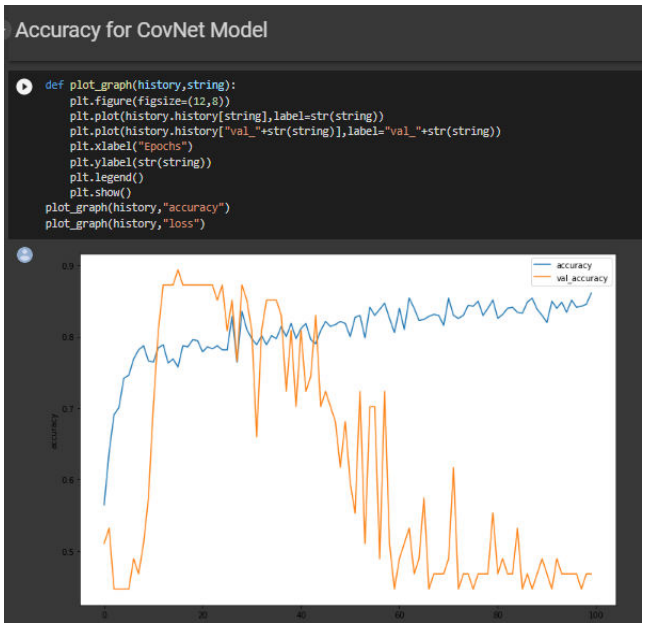

Figure 5: Accuracy Graph

V. CONCLUSION

Early detection of patients with the new coronavirus is crucial for choosing the right treatment and for preventing the quick spread of the disease. Our results showed that the use of deep learning models such as ConvNet, AlexNet and DenseNet are used to extract features by applying the transfer learning concept, and then used these features to classify the chest X-ray images as in normal conditions or positive for COVID-19. The proposed approach was tested on a collection of 116 COVID and 317 normal X-ray images and achieved accuracy of 92%. The proposed classification

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method proved to be very competitive, enabling one to perform an in-depth analysis, necessary to gain qualitative insights into the characteristics of COVID-19 disease.

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