The evaluation of convolutional neural network (CNN) for the assessment of chest X-ray of COVID-19 patients

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Abstract

Aim: The aim of the present study is to assess the diagnostic accuracy of a computer vision-based system for the identification of radiological changes in the lungs of COVID-19 patients.

Materials and Methods: A total of two hundred and seventy-eight (278) images of chest X-rays have been assessed by applying ResNet-50 convolutional neural network architectures in the present study.

Results: A pre-trained ResNet-50 architecture was used to diagnose the cases of COVID-19 patients. The analysis of the data revealed that a computer vision-based program achieved a diagnostic accuracy of 98.18 %, and F1-score of 98.19.

Discussion: The radiological assessment of lung has got paramount importance in the case of COVID-19 patients particularly when these patients are severely ill. The computer vision-based programs may identify and differentiate among the subtle changes in the digital images which may not be detectable or visible to the human eye. Due to the better-automated feature extraction capability, the convolutional neural networks, which have been trained on natural images, turned out to be very successful in the classification of images. In the present study, ResNet-50 convolutional neural network architectures have been applied to the digital images of chest X-rays of COVID-19 patients and it yielded an accuracy of 98.18 % and F1-score of 98.19. The result of the present study is very encouraging and in the near future, it could be a very useful adjunct tool for the assessment of chest X-rays in the case of suspected patients of COVID-19.

Conclusion: The performance of a convolutional neural network regarding the differentiation of pulmonary changes in cases of COVID-19 from the other types of pneumonia on digital images of the chest X-rays is excellent. It could be a very useful adjunct tool for the evaluation of chest x-rays which may be quite helpful for health professionals in patient care.

Keywords

COVID-19; Pneumonia; ResNet-50
Introduction
The outbreak of the novel coronavirus in the Wuhan city and its spread to other countries of the world has created a lot of stress and anxiety among the residents and health professionals around the globe. Coronavirus is an enveloped RNA virus. There are four most common types of human coronaviruses (229E, NL63, OC43, and HKU1) which causes upper respiratory tract infections such as common cold [1]. Some new strains of coronaviruses like SARS-CoV, MERS-CoV, and a recently identified severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) evolved from coronaviruses which are zoonotic in origin and these types can cause cataclysmic ailment in human being. The Middle East respiratory syndrome coronavirus (MERS-CoV) is transferred to human beings from the camels. Civet cats are the source of severe acute respiratory syndrome coronavirus (SARS-CoV) and from these infected cats it is transmitted to human beings. An outbreak of SARS-CoV has been reported from China in 2002-2003 and MERS-CoV has been identified in patients with pneumonia in the Middle East [2–4]. And now the recently identified novel coronavirus (severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been detected in the patients in the Wuhan city of China [5]. The mode of transmission is person to person via respiratory droplets and the median incubation period is four days [6]. The disease is mild in the majority of patients but in some cases, severe to critical illness may occur which is characterized by breathing difficulty to respiratory failure. The severity of the disease is more associated with old age. Pneumonia is the most common problem in the case of severe disease. The patients with pneumonia present with the clinical features of fever, fatigue, dry cough, anorexia, myalgia, dyspnea and sputum production [7]. Radiological imaging is an important tool for the evaluation of lung diseases. In COVID-19, CT scan revealed ground-glass opacification which is usually bilateral and involves the peripheral area of the lower lobe of lungs and the radiological findings may also be present even in subclinical cases [8]. Microbial infections are the most important cause of pneumonia which include bacteria, viruses, and fungi. The differentiation of pneumonia caused by viruses and particularly novel coronavirus - severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) on radiological imaging is a quite difficult task that requires vast experience and strong competency in the field of radiology. The development of computer vision-based programs for the detection of radiological features associated with COVID-19 on the radiological images of the lungs would be a very useful tool to facilitate health professionals in fighting against this lethal pathogen which has affected the whole world. The aim and objective of the present study are to evaluate the usefulness and diagnostic accuracy of a computer vision-based system for the identification of radiological changes in the lungs of patients with COVID-19.

Material and Methods
The research project has been approved by the ethical committee of the University of Lahore. In the present study, two hundred and seventy-eight (278) images of chest X-rays have been evaluated which were acquired from the public repositories provided by the University of Montreal and National Institutes of Health. The acquired data sets from the public repositories are labeled as digital images of normal chest X-rays, chest X-rays with pneumonia and chest X-rays of patients with COVID-19. The digital images of Chest X-rays from these datasets included ninety-three (93) digital images of normal chest X-ray which is labeled as normal, the other dataset is comprised of ninety-six (96) digital images of chest X-rays with pneumonia and this group is labeled as pneumonia while the third dataset contained eighty-nine (89) digital images of chest X-rays of patients diagnosed with COVID-19 and it was labeled as COVID-19.

For the assessment of these digital images of chest X-rays of all three groups, ResNet-50 convolutional neural network architectures have been used [9]. As our dataset was limited, we used the transfer learning approach and pre-trained our models using the ImageNet data [10]. The available X-ray dataset was divided into two classes that included the Training set (80% of the total dataset, i.e., 223 images), and the Testing set (20% of the total dataset, i.e., 55 images). The training set was further divided into 192 images for training and 31 images for validation. We applied several augmentation techniques as well as a 50% dropout to avoid overfitting [11]. A list of the applied augmentations and their descriptions are given in Table 1. All images were resized to 224 × 224 pixels before being fed to the network.

We only trained the last 6-layer of the pre-trained Resnet-50 network and the remaining layers were kept fixed. We used a cyclical learning rate, ranging from 1e-6 to 1e-3 and saved the best model in every cycle using train and validation accuracy. FastAI API was used to run all the algorithms on a PC with Intel-i5 with RTX-2070 GPU and 16 GB of ram.

Table 1. Parameters for Image augmentations

| Type of Augmentation | Description |
|----------------------|-------------|
| Horizontal flip      | A random horizontal flip is applied with probability 0.5. |
| random rotate        | Inputs are randomly rotated with an angle in the range -10 to 10 degrees with a 75% probability. |
| random zoom          | A random zoom in the range of 0 10 10% with a 75% probability is applied. |
| random lighting      | A random lighting and contrast change controlled is applied with a 75% probability. |

Results
The classification results in the form of a confusion matrix for both training and test data are shown in Figure 1. Note that only one image belonging to COVID-19 class has been classified as normal in both training and test data. Similarly, during training, only one of the COVID-19 images was confused as non-COVID-pneumonia. This shows that the COVID-19 X-rays contain significant discriminatory information that can be extracted by a convolutional neural network. Using this extracted information, we can easily differentiate between normal, non-COVID-pneumonia and COVID-19 cases. The results in the confusion matrix are succinctly described in terms of average precision, average recall and F1-scores in Tables 2 and 3. The high value of the F1-score for the test data indicates the efficacy of our proposed method.
COVID-19 has affected more than one million persons from more than one hundred and seventy countries until now and unfortunately, this number may rise in the coming days. The WHO has declared COVID-19 as a pandemic. Extensive efforts are being done to prevent the infection and to control the damage caused by this pathogen but with the passage of time more and more cases are being diagnosed with COVID-19. The most important organ affected in COVID-19 is lung, which leads to inflammatory changes in the lungs and it may cause respiratory insufficiency. The reduced oxygen supply (hypoxia) to the human cells will have deleterious effects on the human living cells and ultimately multi-organ failure may also develop in some cases which have a high mortality rate. The radiological assessment of lung is an important part of patient care in the severely ill patient of COVID-19. The evaluation of radiological imaging is a specialized job and requires the opinion of the consultant radiologist. In the prevailing current scenario, it would be imperative to develop an adjunct tool that could assist the health professionals who are heavily burdened in the current situation. In this regard, one of the important areas is the interpretation of radiological images with the help of artificial intelligence. The application of deep learning machine approached may yield promising results in the detection of morphological changes in the lung of patients of COVID-19 on digital images of chest X-rays. The computer vision-based programs may identify the subtle changes in the digital images which may not be detectable or visible to the human eye. The convolutional neural network has been applied for the diagnosis of tuberculosis on the Chest X-rays and it has revealed very good results [12]. Similarly, another study revealed that deep learning algorithms can help in the identification of lung opacities, enlargement of the heart and pleural effusion on chest X-rays [13]. Due to the better-automated feature extraction capability, the convolutional neural networks which have been trained on natural images turned out to be very successful in the classification of images [14]. The performance of a convolutional neural network related to the imaging modalities with less human intervention has been found to be better than other conventional methods of machine learning [15].

In the present study, ResNet-50 convolutional neural network architectures have been applied which yielded the accuracy of 98.18 %, and F1-score of 98.19. The result of the present study is very encouraging and in the near future, it could be a very useful adjunct tool for the assessment of chest X-rays in the case of suspected patients of COVID-19. The number of cases is one the limitation of this study. The organization and collection of the data of patients of COVID-19 from different countries of the world may be planned and subjected to research for further improvement in the diagnostic modalities.

Conclusion
The performance of a convolutional neural network regarding the differentiation of pulmonary changes associated with COVID-19 from the other types of pneumonia on digital images of the chest X-rays is extremely good. It may be a very useful adjunct tool for the identification of lung changes caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection which is a causative agent of COVID-19.
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Scientific Responsibility Statement
The authors declare that they are responsible for the article’s scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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