Exploring the Deep-Learning Techniques in Detecting the Presence of Coronavirus in the Chest X-Ray Images: A Comprehensive Review

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Abstract
The deadly coronavirus (COVID-19) is one of the dangerous diseases affecting the entire world and is fastly spreading disease. This spread can be reduced by detecting and quarantining the patients at an earlier stage. The most common diagnostic tool for detecting the coronavirus is the Reverse transcription-polymerase chain reaction (RT-PCR) test which is time-consuming and also needs more equipment and manpower. Furthermore, many countries had a deficit of RTPCR kits. This is why it is exceptionally very crucial to develop artificial intelligence (AI) techniques to detect the outbreak of coronavirus. This motivated many researchers to involve deep-learning methods using X-ray images for more decisive analysis. Thus, this paper outlines many papers that used traditional and pre-trained deep learning methods that are newly developed to reduce the spread of COVID-19 disease. Specifically, advanced deep learning methods play a critical role in extracting the features from the chest X-ray images. These features are then used to classify whether the patient is affected with coronavirus or not. Besides, this paper shows that deep learning techniques have probable applications in the medical field.

1 Introduction
The new coronavirus (COVID-19), developed from an extremely intense respiratory disease has become a pandemic universal in very recent times. Both the infected rates and death rates are growing promptly [24, 85]. As of this present time, it is reported that more than 20Cr have been infected and more than 45 lakhs have died because of the Corona [10, 22]. As shown in Fig. 1, the united states is the bad-hit country with the highest number of infected and death cases, while India is the second bad-hit country [17, 71]. The novel coronavirus has caused a financial crisis by putting the world’s population and industrial sectors into quarantine [19, 66]. The most common symptom of the coronavirus comprises of dry cough, fever, and tiredness. The fewer common symptoms are aches and pains, sore throat, diarrhea, headache, loss of taste or smell. However, the serious symptoms are difficulty in breathing, shortness of breath, and chest pain that make the disease more threat to the public [48, 82, 86].

The most common and popular technique used in the diagnosis of the COVID-19 virus is the real-time reverse transcription-polymerase chain reaction (RT-PCR). Other methods such as chest radiology imaging were performed on computed tomography (CT) and X-ray images for initial diagnosis and treatment of the COVID-19 virus [7]. However, the RT-PCR has low sensitivity, it is an efficient method to detect the COVID-19 virus from the radiological images of patients [89]. Computed tomography (CT) is an acute, important, and efficient imaging modality method to detect COVID-19 pneumonia. Even if, the CT images have achieved higher detection sensitivity, the chest X-ray images are the most generally used method to detect the coronavirus [26, 41, 72, 84]. The main reason is chest X-ray images are efficient, low cost, and widely accepted in hospitals.

Chest X-ray images are important clinical, conventional images that play an important role in identifying different pulmonary viruses and diseases. These images are considered as an alternative for screening the detection and classification of nCOVID-19 or to estimate the infectious viruses in the Chest X-Ray images (CXR) [45, 91]. The CXR images of the infected persons exhibit noticeable and observable characteristics. They include bilateral ground-glass opacities, dense pulmonary consolidations, bacterial infection, tuberculosis infection, etc. Despite this, the manual examination of these noticeable infections on the CXR images
is more tedious and tough. Furthermore, the computation time to evaluate the number of infected patients is high and difficult, thus, leading to high fatality and depression [12, 33, 43, 44, 58, 69].

Many radiologists find difficulty in diagnosing the presence of coronavirus because of the difficulty in differentiating between pneumonia caused by a coronavirus and other types of viruses or bacteria. In order to overcome this challenge, many detection and classification methods have been proposed. Artificial Intelligence (AI), an emerging software technology in all areas has directly contributed to coronavirus detection and classification. This helps in providing higher quality results by reducing manpower [51, 75, 80]. The two major areas of AI are deep learning and machine learning which have also contributed more in the field of medical analysis. Many deep learning methods based methods are used in detecting the coronavirus in both the CT and X-ray samples [36, 52, 87, 88]. There are many deep learning methods that are based on the pre-trained model along with transfer learning [27, 63], and customized networks [59, 64]. Many machine learning algorithms are robustly used for the analysis of coronavirus [9, 56], and prognosis prediction. Moreover, technology such as big data [32, 74], smartphone technology [15, 38], and the Internet of things (IoT) [77, 78] is broadly used to enable many results for the fight against the transmission of coronavirus.

1.1 Motivation

The motivation at the other side of this research is the speedy growth of corona cases worldwide. In consideration of the first report of Coronavirus detection in Wuhan, China, in December 2019, it has increased to around the places worldwide. The increase in the spread of corona disease has resulted in forty-five million deaths and three hundred and thirty-four million cases as of October 2021. With the growing issue, many researchers and firms are hunting methods for detecting the presence of the virus at early stages, to lower the spread, and also to analyze the treatment methods. Science and technology are decisive in this complicated matter. Initially, in china, the infected people were identified using facial recognition methods and were dispatched foods and medicines by drones and robots. At the curb to find the treatment for covid-19, Artificial Intelligence (AI) has been massively engaged to expose the methods.

Many researchers explored artificial intelligence methods to determine medications and treatments to cure the disease. These methods involve computer scientists establish on detecting the infected individuals using the X-rays and CT scans. AI is used broadly to detect, track, and diagnose the coronavirus in chest images. There are many review papers related to coronavirus, however, there is no current review paper available that covers the deep-learning methods for the analysis of covid-19. A few other surveys have newly been divulged, but they did not cover much observation of deep learning uses. This encouraged us to write an advanced, state-of-the-art method, that aims to consider and enclose all the aspects of deep learning methods.

1.2 Organisation of the Paper

The main aim of this survey paper is to analyze the recent developments of many deep learning methods that are used for diagnosing the COVID-19 by collecting the data from X-ray images. This work characterizes a survey on different deep learning and machine learning techniques for detecting, classifying, and tracking the coronaviruses from the CXR images. A flowchart is shown in Fig. 2 describes the

Fig. 1 Top affected countries in the world as of October 7, 2021

![Most affected countries worldwide as of October 7, 2021](image-url)
contributions of the review of the papers. The major contributions are:

- Many articles from digital libraries and classified them into deep learning methods.
- To contribute the works and important information in an open, transparent, and available manner by taking the important factors such as methods, data, experiment datasets, and performance metrics.
- Using the X-ray medical samples, comprehensively consider the state-of-the-art methods of deep learning methods based covid-19 diagnosis method.
- To show neatly classified literature in an order to have an exceptional understanding of the methods.
- To feature and match the challenges of the existing covid-19 cases that are purely based on deep learning methods.
- To recommend the future works for the detection of covid-19 methods that are both decisive.

The rest of the paper is as follows: Section 2 shows the general challenges faced during the infection. Section 3 shows the overview of the detection methods. Section 4 introduces the issues and future works of the existing methods. Finally, Section 5 concludes this work.

2 Challenges

The pneumonia was concluded by detecting the bacterial and viral pathogens in the X-ray images. But, in recent days, a new virus namely COVID-19 has become one of the important reasons to cause pneumonia. However, the treatments are different for each pneumonia. For the bacterial infection, the patient requires intensive antibiotic treatment. While viral infections require intensive care. The treatments include an initial screening of the CXR image, detecting the viruses or bacteria, and finally identifying the type of the virus. In the case of the COVID-19 virus, the treatment includes keeping the patients in quarantine for some days, social distancing, and also wearing masks. However, the treatment for COVID-19 is the biggest challenge among the other treatments.

World Health Organization (WHO) has approved many testing methods to diagnose the coronavirus. The most common method, namely, the reverse transmission polymerase chain reaction method (RT-PCR) involves examining and producing an exact copy of the short sequence of DNA or RNA. However, this method has failed in many stages where the patients were made to test for more than one time. The next method is laboratory testing where the results were completely dependent on the proper analysis of X-ray images. There are only limited testing kits and testing laboratories to detect COVID-19 viruses in the patients. Thus, developing an immense and massive challenge to the medical experts.

Usually, the incubation period in the COVID-19 detection is 1-14 days, i.e. the time between catching the virus and starting to have symptoms is high. So, it is a great challenge to identify the virus in the initial stage depending on the symptoms that are seen in the person. However, the failure of detection of COVID-19 viruses may lead to an increase in higher death rates.

It can also be noted that the X-ray images show the viruses in low lobes, posterior segments with the peripheral and subpleural distribution of the lungs. As time progresses, the infection in the lesions increases more and more. Therefore, the biggest challenge is the high computation time to identify the viruses and also the high manpower (medical experts) to examine the X-ray images. Even, there is a need for more computer assistance to help the medical experts in identifying the COVID-19 viruses.
In this current situation, it is difficult to perform a manual diagnosis to identify the viruses. So, there is a critical need for an automatic, definitive, and precise computer-based method to solve the above issue. Thus, the deep-learning and machine-learning techniques in computer methods play an important role in examining the images for detecting pneumonia.

3 Overview of Detection Methods

This section focuses on the process of collecting pertinent research articles. Considering the cases started, a lot of research is carried out to address the detection and diagnose the COVID-19. But, after investigating the research articles, it has been established that many articles share only the detection and diagnosing methods. Thus, it is a deliberate work to analyze the articles which use the deep-learning methods to analyze the problems faced for covid-19. Figure 3 shows the schematic steps used in analyzing the chest X-ray images for detecting the presence of coronavirus (Table 1).

3.1 Traditional Deep-Learning Methods

Convolutional neural networks (CNN) are the more efficient artificial neural networks that contain several layers. Each layer contains many neurons that will work similarly to human brain neurons, thus, proving to be highly decisive in medical image analysis [68]. Tulin et al. proposed a new model for detecting coronaviruses from the x-ray images. The Dark-model classifier has been used in this method to detect the bi-classification and multi-classification. The accuracy of the method is 98.08%. There were a total of 17 convolutional layers and different filtering layers on each layer. This method is implemented in X-ray image Dataset [62].

Another work proposed by Santos et al. performed the classification process by conducting a series of experiments using the supervised learning method. This method used image texture feature descriptors, feed-forward, and convolutional neural networks. The method was designed on the system to automatically detect the COVID-19 disease from the x-rays images. The datasets used were Cohen’s database (25th March), Cohen’s database (18th April), Cohen’s and Kermany’s database - COVID-19 and no findings, and Cohen’s and Kermany’s database - COVID-19, no findings and pneumonia. The accuracy achieved in this method is 93.56% [81]. Chaimae et al. [60] used a residual neural network and two parallel levels of different kernel sizes to extract local and global features from the input images. The dataset used is a combination of 219 COVID-19, 1341 normal, and 1345 viral pneumonia chest x-ray images. The accuracy achieved in this method is 96.69%.

Luca et al. used three methods to detect COVID-19 viruses. (1) detection of the presence of pneumonia, (2) Distinguish between COVID-19 and pneumonia, (3) localize the infected areas in the x-ray. VGG-16 classifier has been used for classifying the viruses from the X-ray images. The three datasets used here are covid-chest X-ray-dataset, X-ray image DataSet, and ChestX-ray8 database. An accuracy of 0.96 has been achieved in this method.
Another new method detected COVID-19 viruses in four phases. They are (1) data augmentation, (2) preprocessing, (3) stage I deep network model designing, and (4) stage II deep network model designing. The datasets used here are chest X-ray images of four different cases: Normal/healthy person, Patient suffering from bacterial pneumonia, viral pneumonia, and COVID-19. The evaluation is performed using the 5-fold-cross method. Thus, the overall accuracy achieved is 95.11% [39].

The work proposed by Khan et al. [44] proposed a new deep convolutional neural network architecture namely CoroNet for the detection of presence of coronavirus in the chest X-ray images. The proposed network used depth-wise layers along with the residual connections.
performance was measured on the dataset of chest X-ray images where a total of 1300 images were used. The proposed system achieved an accuracy, precision, F1-score, and sensitivity of 89.5%, 97%, 98%, and 100%. Another approach proposed by Li and Zhu used a DenseNet and transfer learning for performing the classification on the chest x-ray images. Experiments were performed on ChestX-ray8: Hospital-scale Chest X-ray Database and Benchmarks on Weakly-Supervised Classification and Localization of Common Thorax Diseases dataset. The overall accuracy achieved is 0.889[46]. Wang and Wong [83] used a tailored Convolutional Neural Network and machine-driven design for detecting the virus in the X-ray images. COVIDx datasets were used to perform the training and testing process. The overall accuracy achieved by this method is 91.7%.

Rahimzadeh and Attar [69] proposed a CNN network that was modified by combining the two well-known architectures namely, Xception and ResNet50V2. These two architectures generate features that are more applicable for the classification. A dataset of 15085 chest X-ray images where 180 images were affected by COVID-19, 6054 were pneumonia affected images, and 8851 were normal images. This network obtained an accuracy of 99.50%, the sensitivity of 80.53%, specificity of 99.56%, and precision of 35.27% for the detection of COVID-19.

A new technique presented a fine-tune ResNet-50 architecture called COVID-ResNet to automatically detect the virus in the x-ray images. The experiments were performed on the COVIDx dataset and accuracy of 96.23% is achieved on all the classes [29]. Chandra et al. [23] performed a two-phase classification approach using an automatic COVID screening (ACoS) test by extracting the texture descriptor features from the COVID x-ray images. The two-phase classification is performed using a majority vote-based classifier. Experiments were performed on the three benchmark datasets COVID-Chestxray set, Montgomery set, and NIH ChestX-ray14 set. The overall accuracy achieved using this method is 98.06%.

Xiaowei et al. [90] proposed a region-based segmentation namely, VNet-inception residual network (IR)-region proposal network (RPN) model for detecting the regions. The VNet is connected with the IR structure and is used as a feature extracting part. RPN method captures the region of interest of the healthy region and infected region using 3D bounding boxes. They used a dataset of a total of 618 transverse-section CT samples which were collected with COVID-19 infection from the First Affiliated Hospital, College of Medicine, Zhejiang University; and Wenzhou Central Hospital. The overall accuracy achieved by this method is 86.7%.

Rahimzadeh et al proposed a new concatenated CNN along with Xception and ResNet20v2 models for classifying the COVID-19 cases using the X-ray images. Experiments were performed on 180 images of COVID-19 patients and 8851 images of normal and healthy people. The overall accuracy achieved was 99.56%. Wu et al. [85] proposed a new coronavirus screening framework that is based on the deep learning method and concept of Multiview fusion. The deep learning method used here is the ResNet50. A collection of 495 images were used for analyzing the performance of the proposed method, where 368 were the infected images and 127 were infected with other viruses. This multi-view fusion model method has achieved an accuracy of 76%.

Apostolopoulos et al. [11] created a system that detected the presence of coronavirus automatically by using the concept of transfer learning along with MobileNetv2, VGG19, Inception, Xception, and Inception-ResNetv2. A total of 1427 images were collected, where 448 images were taken for COVID-19 infected viruses, 1414 images were taken for other pneumonia viruses, and 1008 images were for healthy cases. The authors have performed a 10-fold cross-validation method. The overall method achieved a performance of 96.78%.

Abbas et al. [1] classified COVID-19, infected patients, from healthy people using a new system namely deep ResNet18. This system performed Decompose, Transfer, and Compose (DeTraC) that is used to fix any irregularities in the images. A collection of 196 images were used, where 80 images are from normal patients, 102 from COVID-19 infected patients, and 11 are from SARS infected people. The total accuracy achieved by the proposed method is 95.12%. Another method that used a combination of CNN and Whale Optimization Algorithm (WOA) for predicting and curing the coronavirus in the X-ray images was proposed by Elghamrawy and Hassanien [28]. In the system, the WOA was used for predicting the virus and CNN was used for diagnosing the virus. Publicly available databases that contained 617 images were used for analyzing the performance of the proposed method. The proposed method achieved an accuracy of 96.40%.

Gozes et al. [31] proposed a new method that produced a localization map of the lung abnormality and their measurements of both the coronavirus and healthy patients. Indeed, the proposed method was split into two subsystems. The first subsystem used a 3D analysis to detect the nodules small opacities using a well-known commercial off-the-shelf software. The software provided both the measurements and localizations of the lungs. The second subsystem is comprised of three steps: the first step includes the cropping of lung region of interest (ROI) using the lung segmentation module (U-net architecture); the second step includes detecting the coronavirus using deep convolutional neural network model ResNet50; the third step includes the abnormality...
localization detection. Thus, the combination of two subsystems detected the coronavirus.

Ucar et al. [79] proposed a Deep Bayes-SqueezeNet based COVIDiagnosis-Net to detect the presence of coronavirus in the chest X-ray images. The proposed method contains three main stages: offline augmentation, Bayesian optimization, and decision-making. The offline augmentation is performed on the raw dataset. The Bayesian classification performed is based on the SqueezeNet model. Finally, the decision-making is made based on the testing phase. The dataset used here is the COVIDx dataset which consists of a total of 5949 X-ray images. An accuracy of 98.3% has been achieved by the proposed method. Yet, an interesting method proposed by Bandyopadhyay et al. [14] proposed a new model that used the concept of a Deep-learning Neural Network. The framework consists of Long short-term memory (LSTM) and a Gated Recurrent Unit (GRU) that automatically detects the presence of coronavirus in the X-ray images. These units were used for finally training the dataset. The proposed method showed an accuracy of 87% (Table 2).

### 3.2 Pre-Trained Models

The pre-trained models are the deep-learning methods that exploit the gained and known knowledge from the previous training itself. This training is then applied to the new set of models. The pre-trained models are developed based on CNN [65]. Thus, a research work, that involved the detection of coronavirus using eleven pre-trained CNN models and a Support Vector Machine (SVM). The eleven pre-trained CNN models were used for automatic extraction of features and the classification part was carried out by SVM. Two different datasets were used for analyzing the performance of the proposed method, where the first dataset included 25 positive COVID-19 and 25 healthy X-ray images and the second dataset included a total of 133 images. The overall accuracy achieved by this method was 95.38% [73].

Horry et al. [35] used four popular pre-trained CNN models along with the transfer learning namely, VGG, Inception, Xception, and Resnet. A total of 400 images were used for analyzing the performance of the proposed method. The images were classified into three classes, where, 100 images - COVID-19 infected images, 100 images - pneumonia, and 200 images - healthy cases. The experimental results show that an accuracy of 80% was achieved by the above method.

Deng et al. [25] proposed live Keras-related deep learning models that include ResNet50, InceptionResNetV2, Xception, transfer learning, and pre-trained VGGNet16 to design an approach for detecting and classifying the presence of coronavirus in X-ray and CT images. Support vector machines and Conventional Neural Networks are the two benchmark methods that have been compared with the other approaches. The dataset included 5857 Chest X-rays and 767 Chest CT images. The accuracy achieved for the X-ray images was 84% and CT images were 75%.

Another interesting research proposed by Shorfuzzaman et al. [76] showed the efficiency of convolutional neural network (CNN) by combining the CNN-based pre-trained models and a classifier to detect the coronavirus. The CNN-based pre-trained models are used as feature extractors to sustain the transfer learning. The proposed method is then compared with the five different pre-trained models through 5-fold cross-validation. The accuracy showed is higher than the other methods.

Another new method that involved the combination of the grid search strategy and three pre-trained models of CNN was used to predict the COVID-19 infection [61]. The CNN pre-trained models are ResNet50, GoogleNet, and ResNet18. The grid search technique is used to select the hyperparameters from the image. Feature extraction and classification are performed by CNN pre-trained models. Three public datasets were used to test the performance of the proposed method, where, 242 images were under bacterial infection, 131 images were under COVID-19 cases, 200 were normal images, and 148 were viral cases. The overall accuracy achieved by the proposed method is 97.69%.

The automatic detection method for identifying the coronavirus in chest X-ray images uses an automated deep convolution neural network-based pre-trained transfer model. The pre-trained models such as Visual Geometry Group (VGG)-16, VGG-19, MobileNet, and InceptionResNetV2 are combined with deep CNN for detecting the coronavirus from 348 chest X-ray images. The accuracy achieved by InceptionResNetV2 models was 97% and proves to be better than other pre-trained models [54].

Rehman et al. [70] used pre-trained knowledge along with transfer learning techniques and the method was compared with many CNN architectures to detect the COVID-19. Performance parameters such as K-fold (10) were used to analyze the performance. The accuracy was achieved is 98.75%. A Deep Convolutional Neural Network model namely CoroNet to automatically detect the coronavirus in X-ray images. This method is based on the Xception architecture pre-trained on the two publicly available datasets namely: ImageNet dataset and chest pneumonia X-ray dataset images. The experimental results show that the proposed method has achieved an accuracy of 89.6% [41].

A new deep transfer learning was introduced to foresee the corona infection from the X-ray images. A total of 100 X-ray images where 50 images with corona infection and the other 50 images were healthy human’s x-ray images was taken from the Github repository. The proposed data transfer method when compared to the state-of-the-art methods exhibited the highest accuracy of 97.82% [12].

Similarly, another method proposed by Ahammed et al. [4] used many deep learning classifiers namely:
| Authors          | Technique                                                                 | Dataset                                                                                      | Challenges                                                                                     | Metrics  |
|------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|----------|
| Sethy et al. [73] | Eleven pre-trained CNN models and a Support Vector Machine (SVM) on deep features | Two publicly available Chest X-ray images                                                   | Statistical analysis is carried out to select the classification process                       | 95.38    |
| Horry et al. [35] | Pre-trained CNN models along with the transfer learning namely, VGG, Inception, Xception, and ResNet | Three sets of Chest X-ray images                                                             | Effects of a false negative                                                                     | 82       |
| Deng et al. [25]  | Keras-related deep learning models that include ResNet50, InceptionResNetV2, Xception, transfer learning, and pre-trained VGGNet16 | 5857 Chest X-rays and 767 Chest CT images                                                   | Further clinical studies may affect the effectiveness                                          | 84, 75   |
| Shoruzzaman et al. [76] | CNN-based pre-trained models and a classifier                               | chest X-ray images                                                                          | Multi-modal problem                                                                            | 98.15    |
| Ozcan et al. [61] | Grid search strategy and three pre-trained models of CNN                  | Three sets of Chest X-ray images                                                             | To increase the efficiency of transfer-learning, many premodel methods should be employed   | 97.69    |
| Mohammadi et al. [54] | Automated deep convolution neural network-based pre-trained transfer model | Chest X-ray images                                                                           | usage of limited number of samples                                                              | 94.75    |
| Rehman et al. [70] | Trained knowledge along with transfer learning techniques                  | Chest X-ray images                                                                           | Accuracy should be improved further                                                             | 98.75    |
| Kanne et al. [41] | Deep Convolutional Neural Network model namely CoroNet and Xception architecture | ImageNet dataset and chest pneumonia X-ray dataset                                           | Models were validated on the pre-trained dataset                                               | 89.6     |
| Apostolopoulos et al. [12] | Transfer learning with pretrained models                                    | Two sets of chest Xray images                                                                | Less exposure to the technique by the medical staffs                                           | 97.82    |
| Ahammed et al. [4]  | Convolutional neural network (CNN), deep neural network (DNN), and different pre-trained models | COVID-19 Radiography Database chest X-ray images                                           | Dataset size is relatively small                                                               | 94.03    |
| El Asnaoui. [27]  | Comparative study of pre-trained models                                    | 6087 Chest X-ray images                                                                      | Accuracy needs to be improved                                                                  | 92.18, 88.09 |
| Minaee et al. [53] | Deep-COVID along with deep transfer learning and pre-trained models       | COVID-X-ray-5k chest X-ray images                                                            | Small size and incomplete dataset                                                              | 100      |
| Islam et al. [37] | Convolutional neural network (CNN) and long short-term memory (LSTM)      | 4575 X-ray images                                                                             | The method need to explore many methods to improve the accuracy                               | 99.4     |
| Benbrahim et al. [18] | Deep transfer learning method using the Convolutional Neural Network and pre-trained models | chest X-ray images collected from Kaggle repository                                          | Limited dataset                                                                                | 99.01    |
| Abraham et al. [2]  | Multi-CNN and a combination of different pre-trained CNNs                  | Two publicly available datasets                                                               | Failed to detect accurately                                                                   | 97.44    |
| Asif et al. [13]  | DCNN based model Inception V3                                              | Chest X-ray image datasets                                                                    | Implementation on different datasets                                                           | 98       |
| Hemdan et al. [33] | COVIDX-Net                                                                 | of Covid-19 X-ray images                                                                      | Needs more dataset for better classification                                                   | 89 and 91 |
| Narin et al. [57] | Pre-trained CNN based models                                               | X-ray images                                                                                 | Technique used in this study may lead to overfitting                                           | 94       |
| Barstungan et al. [16] | Pre-trained deep learning architectures                                   | the Corona infection from X-ray images                                                        | Quantitative analysis need to be improved                                                       | 95.52    |
| Loey et al. [47]   | deep transfer learning with Generative Adversarial Network (GAN) and CNN models | Chest X-ray images                                                                           | the proposed technique needed higher processing power                                          | 85.2 and 100 |
| Bukharia et al. [21] | Pre-trained CNN model namely Resnet50                                     | Chest X-ray images                                                                           | Detection process needs to be made better                                                       | 98.18    |
Table 2 (continued)

| Authors          | Technique                                                                 | Dataset                        | Challenges                                      | Metrics |
|------------------|---------------------------------------------------------------------------|--------------------------------|-------------------------------------------------|---------|
| Punn and Agarwal [67] | pre-trained models                                                       | chest X-ray images             | Lacked robustness                               | 98      |
| Narin et al. [58]  | Three deep Deep Convolution Neural Network (DCNN) architectures based on the pre-trained models | Chest X-ray images             | Method can be extended with more pre-trained models | 98      |
| Ahuja et al. [6]   | Augmentation using stationary wavelets, detection using pre-trained CNN model, and abnormality localization in CT scan images | CT images                      | System can use more validation method on dataset | 99.4    |
| Gonzalez et al. [30] | Segmentation and pre-trained models                                      | Challenge chest X-ray dataset  | High-quality predictions must be explored        | 95      |
| Kamal et al. [40]  | Eight pre-trained models                                                 | Two chest X-ray images         | The method should be improved by working on more datasets | 98.69   |
| Albahli et al. [8]  | Three pre-trained models                                                 | Chest X-ray images             | Accuracy needs to be improved                   | 92      |
| Hira et al. [34]   | Deep learning-based nine CNN model                                       | Binary and multi-class chest X-ray image datasets | Lacking the robustness and limited utility     | 99.32, 97.55 |
| Afshar et al. [3]   | called COVID-CAPS                                                         | Chest X-ray images             | Accuracy needs to be improved                   | 95.7    |
| Afsar et al. [5]    | CNN-based COVID-CAPS                                                      | Chest X-ray images             | Data imbalanced between the used datasets        | 95.7    |
| Kassania et al. [42] | Deep learning-based feature extraction methods                          | Two sets of chest X-ray image datasets | The method was accurate within the range        | 99      |
| Asif et al. [13]    | DCNN based model Inception V3                                            | Chest X-ray image datasets     | Implementation on different datasets             | 98      |
| Moutounet-Cartan [55] | Pre-trained models                                                       | Chest X-ray images             | Low number of data                               | 84.1    |
| Maguolo and Nanni [49] | Pre-trained model named AlexNet                                           | Chest X-ray images             | Limited quantity of the training and testing data | 99.97   |
convolutional neural network (CNN), deep neural network (DNN), and different pre-trained models such as Residual Neural Network (ResNet50), Visual Geometry Group Network 16 (VGG16), and Inception network V3 (InceptionV3) that engaged transfer learning on the COVID-19 Radiography Database chest X-ray images. The method also used basic machine learning algorithms support vector machine (SVM), random forest (RF), k-nearest neighbor (k-NN), logistic regression (LR), Gaussian naive Bayes (GNB), Bernoulli naive Bayes (BNB), decision tree (DT), Xgboost (XGB), multilayer perceptron (MLP), nearest centroid (NC) and perceptron for fine-tuning the parameters. The highest accuracy achieved by the proposed method is 94.03%.

Another method proposed by El Asnaoui. [27] conducted a comparative study of the deep learning methods namely: VGG16, VGG19, DenseNet201, Inception_ResNet_V2, Inception_V3, Resnet50, and MobileNet_V2 to detect and classify the coronavirus from the X-ray images. The experiments were conducted on 6087 X-ray images. The performance analysis has shown that inception_Resnet_V2 achieved an accuracy of 92.18% and Densnet201 achieved an accuracy of 88.09%. Minaee et al. [53] proposed a new system that contained a simple and efficient framework namely, Deep-COVID, where the detection of coronavirus was performed with the help of the concept of deep transfer learning and pre-trained models. The pre-trained models included are DenseNet-121, ResNet50, SqueezeNe, and ResNet18. The performance evaluation was performed on the dataset named COVID-Xray-5k, where it consists of a total of 5071 images. The accuracy achieved by the proposed method of 100%.

Automatic detection of Coronavirus from the X-ray images by the combination of convolutional neural network (CNN) and long short-term memory (LSTM) is proposed by Islam et al. [37]. The CNN has been used for extracting the features and LSTM has been implemented for diagnosing the COVID-19 virus. 4575 X-ray images were used for performing the experiments. A total of 99.4% accuracy has been achieved in detecting the virus in the lung image.

Another automatic detection of coronavirus in the chest X-ray images used a deep transfer learning method using the Convolutional Neural Network (CNN) based models Inception V3 and ResNet50 along with Apache Spark framework. Performance evaluation is performed on the chest X-ray images collected from the Kaggle repository and the overall accuracy achieved by the InceptionV3 model is 99.01% proving to be highly efficient [18].

Abraham et al. [2] examined the efficiency of the multi-CNN and a combination of different pre-trained CNNs for detecting the presence of coronavirus in chest X-ray images. The detection process was carried out by the combination of a feature predictor and a Bayes net classifier. The performance evaluation is performed on two publicly available datasets where the datasets contain both COVID-19 and NON-COVID-19 images. The accuracy achieved by the method (97.44%) shows the efficacy of pre-trained multi-CNN over single CNN in the detection of COVID-19.

Asif et al. [13] used DCNN based model Inception V3 with transfer learning to improve the accuracy of the detection process. The performance was analyzed with the available chest X-ray image dataset and the accuracy achieved is 98%. However, the efficiency has to be improved by using the method on different datasets. To overcome this issue, Mangal et al. [50] proposed a new model namely Covid-AID: which is a COVID-19 artificial detector to analyze the presence of coronavirus in chest X-ray images. The performance evaluation is done on the publicly available dataset namely: covid-chest X-ray dataset. The accuracy achieved by the model is 90.5%. However, the major limitation is that the accuracy needs to be increased by using many datasets.

The next method proposed by Hemdan et al. [33] used a new deep learning classifiers framework called “COVIDX-Net” to detect the Covid19 automatically. The developed COVIDX-Net contained seven DCNN architectures namely: VGG19, DenseNet121, ResNetV2, InceptionV3, Inception-ResNetV2, Xception, and MobileNetV2. This framework allows the classifying of Covid19 X-ray images into positive and negative cases. The proposed system used a dataset including 50 X-ray images to analyze the performance and the VGG19 and DenseNet201 architectures achieved an F1 score of 89% and 91%.

A new automatic detection system using three different CNN-based models such as ResNet50, Inception-ResNetV2, and InceptionV3 were used for detecting the Corona infection in the X-ray images. They used 100 X-ray images (repository in Kaggle) where 50 images were from Corona patients and the other 50 images were from healthy persons. The overall accuracy achieved by this method was 94% [57].

Support vector machine used many deep features that were extracted from deep learning architectures, namely, AlexNet, VGG16, VGG19, GoogleNet, ResNet18, ResNet50, ResNet101, InceptionV3, Inception ResNetV2, DensNet201, and XceptionNet for detecting the Corona infection from X-ray images. Experiments were conducted on 50 images that were downloaded from Github and Kaggle. The accuracy obtained by the overall method is 95.52% [16].

Another novel system for diagnosing the coronavirus using deep transfer learning with Generative Adversarial Network (GAN) and CNN models was proposed by Loey et al. [47]. The CNN models are pre-trained models and used here are Alexnet, Googlenet, and Resnet18. A collection of 307 images where the images fall under four classes like COVID-19, normal, pneumonia_ac, and pneumonia_tr. Different CNN models achieved different accuracy. Googlenet and Alexnet have achieved an accuracy of 85.2% and 100%.
Moutoune-Cartan [55] used variants of CNN architecture namely VGG-16, VGG-19, InceptionResNetV2, InceptionV3, and Xception for identifying the COVID-19 virus from X-ray images. A Collection of 327 X-ray images were used to test the performance of the proposed method. The training and testing process has been carried out using the 5-fold cross-validation method. The overall accuracy achieved by the method is 84.1%. Bukharia et al. [21] developed a new COVID-19 diagnosis system that used a pre-trained CNN model namely Resnet50. The dataset that was used here consists of a total of 278 X-ray images where 89 samples of COVID-19 infected, 93 samples of healthy participants, and 96 samples of pneumonia patients. The overall accuracy achieved by the proposed method is 98.18%.

Punn and Agarwal advanced a new automatic COVID-19 detection system that used pre-trained models namely, Inception ResNet-v2, Inception-v3, DenseNet169, ResNet, and NASNetLarge. The automatic system used many methods for fine-tuning the features called transfer learning. In this system, a collection of 1076 chest X-ray images were used for training and testing purposes. The overall accuracy achieved here is 98% [67]. Moreover, Maguolo and Nanni [49] used a popular pretrained model named AlexNet for detecting the presence of COVID-19 virus in X-ray images. A total of 339271 images were used for evaluating the performance of the proposed system. The training and testing were split using the 10-fold cross-validation method. The overall accuracy achieved by the proposed method is 99.97%.

Narin et al. [58] used three Deep Convolution Neural Network (DCNN) architectures to detect the coronavirus in the X-ray images. The designed DCNN was based on the pre-trained models: ResNet50, Inception_V3, and Inception_ResNet_V2. The proposed method used a transfer learning technique to overcome the limited number of datasets and the cross-validation method that used the k-fold method where the k value is assigned as 5. The dataset that consists of 100 images, where 50 images were from COVID-19 infected images and another 50 images were from healthy X-ray images were used for testing the performance. The overall accuracy achieved is 98%.

The method designed by Ahuja et al. [6] used a three-phase detection model to enhance the accuracy of the detection process. The three phases comprise augmentation using stationary wavelets, COVID-19 detection using a pre-trained CNN model, and abnormality localization in CT scan images. The experimental evaluation uses many pre-trained architectures, such as ResNet18, ResNet50, ResNet101, and SqueezeNet. Results show that ResNet18 performs better than the other methods. The accuracy achieved by the ResNet18 is 99.4%.

Yet another efficient method that manipulates Mahalanobis distance between the feature space to reduce the out-of-distribution problem. The method was then combined with other state-of-the-art segmentation methods and is assessed with the pre-trained models to analyze the experimental evaluation [30].

Kamal et al. [40] used eight pre-trained models namely: VGG, InceptionV3, ResNet, MobileNet, DenseNet, NASNetMobile, AlexNet, and CNN for transfer learning and fine-tuning on the datasets. The performance evaluation is performed on two datasets: the COVID-19 dataset and the Pneumonia dataset. The results show that DenseNet 121 outperforms the other methods. The accuracy achieved by DenseNet is 98.69%.

Similarly, the automatic detection of the presence of coronavirus in the chest X-ray images was achieved by using the three pre-trained models namely: DenseNet, InceptionV3, and Inception-ResNetV4. The performance evaluation was examined by Receiver Operating Characteristic (ROC) using the 5-fold cross-validation method. The performance analysis shows that the pre-trained DenseNet model has achieved 92% [8].

Another work proposed by Hira et al. [34] used a deep learning-based approach to automatically differentiate the COVID-19 disease patients from viral pneumonia, bacterial pneumonia, and healthy (normal) cases. A deep transfer learning approach is used on both binary and multi-class datasets. They have also used nine convolutional neural network-based architecture namely: AlexNet, GoogleNet, ResNet-50, Se-ResNet-50, DenseNet121, Inception V4, Inception ResNet V2, ResNetXt-50, and Se-ResNetXt-50 for the process of classification. The accuracy achieved for the binary and multi-class datasets was 99.32% and 97.55% respectively. The method proposed by Afshar et al. [3] shows a different framework that is based on the Capsule Networks, which is also called COVID-CAPS for detecting the presence of coronavirus in the chest X-ray images. The CNN-based COVID-CAPS shows the highest accuracy of 95.7% on the datasets.

The method proposed by Afsar et al. [5] shows a different framework that is based on the Capsule Networks, which is also called COVID-CAPS for detecting the presence of coronavirus in the chest X-ray images. The CNN-based COVID-CAPS shows the highest accuracy of 95.7% on the datasets. Another method proposed by Ahmed et al. analyzes the deep learning models namely: SqueezeNet, MobileNetV2, InceptionV3, AlexNet, and DenseNet201 with the fine-tuning without pre-trained weights and with the updated pre-trained weights using the augmentation method. Performance evaluation was performed on X-ray images and the accuracy achieved by the proposed method is 98.45%.

Another detection method compared deep learning-based feature extraction methods namely: MobileNet, DenseNet, Xception, ResNet, InceptionV3, InceptionResNetV2, VGGNet, NASNet for the detection of coronavirus in chest X-ray images. The proposed method was then combined with other state-of-the-art segmentation methods and is assessed with the pre-trained models to analyze the experimental evaluation [30].

The method designed by Ahuja et al. [6] used a three-phase detection model to enhance the accuracy of the detection process. The three phases comprise augmentation using stationary wavelets, COVID-19 detection using a pre-trained CNN model, and abnormality localization in CT scan images. The experimental evaluation uses many pre-trained architectures, such as ResNet18, ResNet50, ResNet101, and SqueezeNet. Results show that ResNet18 performs better than the other methods. The accuracy achieved by the ResNet18 is 99.4%.
images. Performance evaluation was performed on two publicly available datasets. The accuracy achieved by the DenseNet121 feature extractor is highest (99%) and proved the efficiency of the proposed method. However, the detection method was accurate within the range [42].

4 Open Issues and Future Work

At present, the world is showing many efforts to finalize a plan for the pandemic that happened because of COVID-19. This paper outlines the deep-learning-based research works that were recently described by the entire research community. Many deep-learning methods such as CNN, RNN, LSTM, and other methods for the detection process are used widely by researchers. The models discussed by the researchers alleged that the percentage of detection of the presence of coronavirus is 100% while others claim it to be 80% to 90%. As there are many advantages is CXR images, many researchers use chest X-ray images for the prediction process. It has been proved that the symptoms such as cold, cough, and chest congestion are more easily identified and extracted from the chest X-ray images than the CT scans.

This paper briefs a total of recent papers of articles that use chest X-ray images for the detection of COVID-19. The researchers reported the analysis based on the current pandemic situation or traditional or pre-trained deep-learning methods where the features are automatically extracted from the images. Among all, 34 articles summarise the deep-learning-based pre-trained method though 20 articles outline traditional deep-learning methods. This study explains that the detection of COVID-19, using deep-learning methods is more efficient, decisive, and dynamic.

The data sources used for detection of the coronavirus in the chest X-ray images are listed in Tables 1 and 2. The article uses different datasets and methods. However, the predictions are not accurate, the world is again facing the second wave of a pandemic wave. At present, many researchers are determinedly working on getting the solutions for this deadly virus, thus it is an open issue. Coronavirus is changing the pattern and the infection rate is also growing up. Many researchers may analyze the solutions to solve the problem and also must develop more datasets to analyze.

5 Conclusion

In this paper, various methodologies, concepts, and algorithms for the detection of the presence of coronavirus in chest X-ray images have been highlighted. The datasets used by the methods have been reviewed. The performance metrics such as accuracy have been analyzed. This survey will be helpful to know the various deep-learning detection methods in COVID-19 detection. Nonetheless, because of the highest number of studies that are updated daily, this survey can be further extended in different directions.

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