Convolutional neural network for the detection of coronavirus based on X-ray images

Essam Hammodi Ahmed, Majid Razaq Mohamed Alsemawi, Mohammed Hasan Mutar, Hatem Oday Hanoosh, Ali Hashem Abbas
Department of Computer Techniques Engineering, College of Information Technology, Imam Ja'afar Al-Sadiq University, Samawah, Iraq

Article Info

Article history:

Received Sep 2, 2021
Revised Jan 1, 2022
Accepted Jan 30, 2022

Keywords:

Convolutional neural network
COVID-19 detection
Evaluation measurements
Healthcare
X-Ray images

ABSTRACT

Nowadays, the coronavirus disease (COVID-19) is considered an ongoing pandemic that spread quickly in most countries around the world. The COVID-19 causes severe acute respiratory syndrome. Moreover, the technique of chest computed tomography (CT) is a method used in the detection of COVID-19. However, the CT method consumes more time and higher-cost as compared with chest X-ray images. Therefore, this paper presents convolutional neural network (CNN) algorithm in the detection of COVID-19 by using X-ray images. In this method, we have used a balanced image database for the normal (healthy) and COVID-19 subjects. The total number of image database is 188 samples (94 healthy samples and 94 COVID-19 samples). Furthermore, there are several evaluation measurements are used to evaluate the proposed model such as accuracy, precision, specificity, sensitivity, F-measure, G-mean, and others. According to the experimental results, the proposed model obtains 98.68% accuracy, 100% precision, and 100% specificity. Besides, the proposed model achieves 97.37%, 98.67%, and 98.68% for sensitivity, F-measure, and G-mean, respectively. The performance of the proposed model by using CNN algorithm shows promising results in the detection of COVID-19. Also, it has outperformed all its comparatives in terms of detection accuracy.

Corresponding Author:

Hatem Oday Hanoosh
Department of Computer Techniques Engineering, College of Information Technology
Imam Ja'afar Al-Sadiq University
Samawah, 66001, Al Muthanna, Iraq
Email: hatem.oday@sadiq.edu.iq

1. INTRODUCTION

The coronavirus disease (COVID-19) has appeared at the end of december 2019 in Wuhan city, China as the first case of this virus, where the pandemic of this respiratory disease is still infecting people nowadays. However, COVID-19 disease is considered a dangerous pandemic around the world [1]. In fact, COVID-19 is a respiratory illness that has been caused by severe acute respiratory syndrome coronavirus 2 (i.e., SARS-CoV-2) [2]. The most familiar symptoms for COVID-19 are short breathing, headache, fever, diarrhoea, sore throat, and cough. Moreover, other symptoms can be observed also in the patients of COVID-19 such as loss of smell, taste vanishing, nasal blockade, aches, and tiredness [3]. However, people can be infected quickly by the coronavirus droplet because there is no particular vaccine prepared to work efficiently 100% to prevent coronavirus and infectious disease. Consequently, the isolation of the infected people from COVID-19 is the only manner to stop and prevent the spread of COVID-19 to avoid infect healthy people. Furthermore, the real-time reverse transcription polymerase chain reaction (i.e., RT-PCR) is the common method that used for COVID-19 detection by utilizing respiratory samplings [4]. Although the RT-PCR technique can work effectively for SARS-CoV-2 diagnosis, this method has some drawbacks such as error-prone results and time consumption [5]. According to the limitations and drawbacks of the RT-PCR technique, it has been posed as challenge to prevent and stop the dissemination of COVID-19 infection.

In contrast with the RT-PCR method, the techniques of radiological imaging have been used in the diagnosis of SARS-CoV-2 though coalescing with clinical symptoms of the infected people, obtain the history of travel and laboratory results [6]. In addition, the techniques of radiological imaging (e.g., chest CT-scan and chest X-ray) can be presented as helpful and significant tools in order to isolate the infected people appropriately and also to control this situation of the COVID-19 epidemic [7]. The chest CT-scan and chest X-ray techniques can be used in the detection of the COVID-19 radiological characteristics. The chest X-ray is the first selection of radiologists because most hospitals and clinics are provided with machines of X-ray [8]. Nevertheless, the chest CT-scan technology is consuming more time as compared with the technology of X-ray imaging. Moreover, in different undeveloped regions, the quantity and the quality of the chest CT scan may be limited or low. Therefore, it leads to an unsuitable detection of COVID-19. On the other hand, the chest X-ray is a well-known technique and broadly available, where it has been widely used in diagnostic imaging and plays a significant role in epidemiological research and clinical care [9]. Further, many facilities of ambulatory care have deployed machines of chest X-ray imaging in rural regions particularly. X-ray imaging is performing significantly in real-time for disease detection. Algorithms of deep learning (DL) and machine learning (ML) have widely used and proved their efficiency and effectiveness in the classification process [10], [11], where such algorithms have been used in several domains such as language identification [12]–[14], images classification in the medical domain [15], [16], identification of spam emails [17], vehicle detection [18], detection of conflict flows in SDN [19], and voice pathology detection [20]–[23]. Besides, DL and ML algorithms have been applied as the main part in the systems of COVID-19 detection [24], [25]. The main intention of using DL and ML algorithms is to train and create a system that can classify subjects efficiently. Many methods and techniques have been proposed in the field of COVID-19 detection. Recently, the detection of COVID-19 has witnessed a significant interest by researchers and developers, where it has been observed that there are many systems for COVID-19 detection that have been proposed in the state-of-the-art which used chest X-ray images.

The study in [26] has been presented a deep learning technique for the detection of COVID-19 by using X-ray images. The authors have used convolutional neural network (CNN) algorithm and selected 70 samples of X-ray images for patients who are infected by COVID-19. These X-ray images have been taken from the public database [27]. While the normal (healthy) samples for chest X-ray images have been obtained from Kaggle. According to the results, the CNN can be improved the precision measure from 85.7% to 92.9% for the VGG16 method. Furthermore, the authors have created saliency maps in order to demonstrate the locations focused over the deep network, facilitate a more informed the process of decision-making, and finally to enhance the understanding of deep learning outcomes.

In addition, there are three different models of CNN techniques that have been proposed in [28], these models are ResNet50, InceptionV3, and Inception-ResNetV2. Besides, these three models have been used for the detection of people who are infected by COVID-19 disease by using images of X-ray. In this study, the authors have been selected the X-ray images for healthy samples and COVID-19 samples from [27]. The total number of the database is 50 images (i.e., 25 samples for the COVID-19 subject and 25 samples for the healthy subject). The evaluation results of this method have shown that the ResNet50 model has achieved the best detection accuracy of COVID-19 as compared with Inception-ResNetV2 and InceptionV3 models, where the ResNet50 model has obtained accuracy reached to 98%. While the highest achieved accuracies of Inception-ResNetV2 and InceptionV3 models were 87% and 97%, respectively. However, this study has been investigated based on a small database of X-ray images.

Another research study has been proposed in [29]. In this study, the authors have presented the ResNet model of the deep learning technique for diagnosing the COVID-19 from images of chest X-ray. Furthermore, this study consists of two phases. The first phase is for the classification part between COVID-19 samples and healthy samples. While the second phase is to identify the anomaly samples. In the second phase, it gives an anomaly score in order to improve the COVID-19 score that has been used for the classification part. The authors have been selected two databases of X-ray images in their study that involves 70 samples for the COVID-19 subject and 585 samples for the healthy subject. The assessment outcomes for COVID-19 detection of this study have shown that the measurements of AUC (i.e., area under the curve), sensitivity, and specificity were 0.952, 96.00%, and 70.7%, respectively.

Regarding COVID-19 detection, a framework model that depends on Capsule Networks has been presented in [30] for detecting COVID-19 through using X-ray images. In addition, different convolution layers and capsules have been used in this work in order to overcome the class imbalance problem. In the experimental of this study, the authors have shown that the performance of their method is able to detect

COVID-19 based on a smaller number of trainable parameters. Besides, they have been mentioned that the trained model is available online on GitHub [31]. According to the results, the highest achieved accuracy was 95.7%. Whilst, the highest obtained specificity and sensitivity were 95.80% and 90%, respectively. The research study in [32] has been presented the support vector machine (SVM) algorithm in the diagnosis of COVID-19. In this method, there were thirteen different pre-trained models of CNN such as VGG19, VGG16, AlexNet and other models. The deep features have been extracted from 381 samples of chest X-ray images. Where there were 127 samples of images that have been selected for those patients who are infected with COVID-19 subject, 127 samples have been selected to viral pneumonia subject. Whereas, there were 127 samples have been selected for the healthy subject. Subsequently, the deep extracted features have been fed into the SVM algorithm in order to classify the chest X-ray images with respect to their subjects. In this method, the images database has been divided into 80% training and 20% testing. The results of this method have shown that the SVM classifier is able to obtain average classification accuracy that reached to 95.33% for COVID-19 detection.

2. RESEARCH METHOD

The CNN has been widely used and proved its efficiency and effectiveness in the classification process. Therefore, in this study, our proposed model is performed based on the CNN algorithm for detecting COVID-19 based on X-ray images. Besides, there are various evaluation measures have been used in order to evaluate the performance of the proposed model in terms of effectiveness. Furthermore, the proposed model has been created based on three main steps. The first step indicates the database of the X-ray images that have been used in this model. The second step indicates to the pre-processing process of the X-ray images for both subjects, COVID-19 and healthy. The third step indicates to both tasks of features extraction and classification, where the CNN algorithm is used in order to distinguish the X-ray images with respect to their subject. The diagram of the proposed model for COVID-19 detection is illustrated in Figure 1. In addition, these three steps of the proposed model will be explained in the next subsections, respectively.

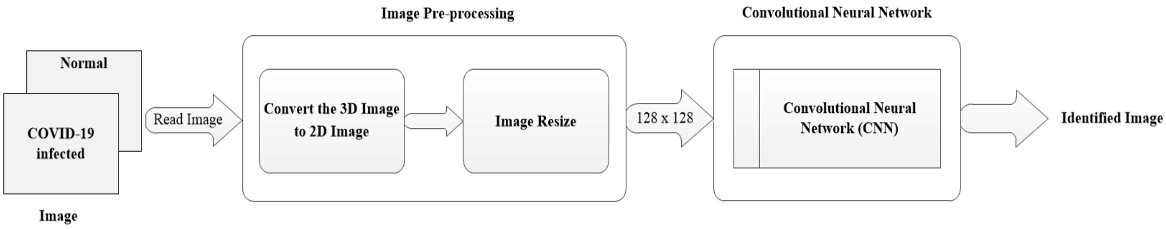


Figure 1. The diagram of the proposed model

2.1. X-ray images database

In our proposed model, the database of X-ray images has been taken from [27]. This database includes two main classes, the first class denotes to the healthy samples (i.e., people who are uninfected from COVID-19). Whilst, the second class denotes to the samples of patients who are infected by COVID-19. In the proposed model, the total number of X-ray images is 188 samples. The healthy class includes 94 samples of X-ray images and the COVID-19 class includes 94 samples of X-ray images as well. Furthermore, the database in this proposed model has been divided into 60% for the training process (i.e., the total is 112 samples, each class includes 56 samples). The remaining 40% of the database is for the testing process (i.e., the total is 76 samples, each class includes 38 samples). Further, Table 1 shows the details of the database used in the proposed model.

Table 1. Description of the database

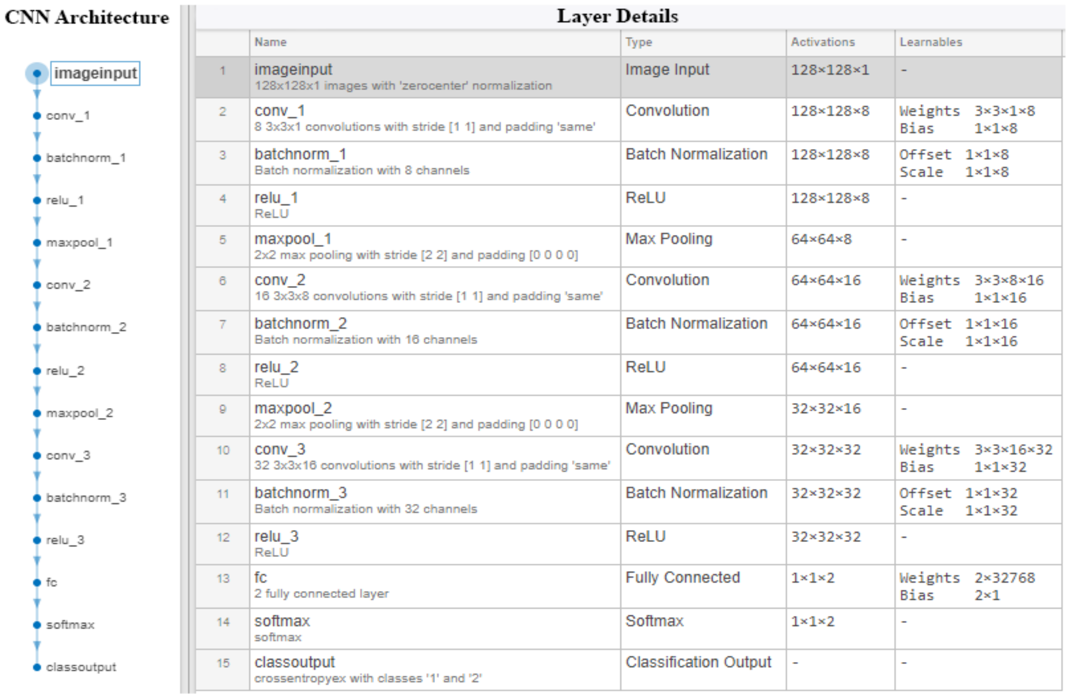
Class	Number of Images	Samples of X-ray images	Class Label
Normal (Healthy)	94		1
COVID-19	94		2

2.2. Image pre-processing

In this study, the pre-processing step of X-ray images consists of two phases. These two phases are the conversion of the image and image resize. In the conversion phase, each image will be read and check its dimensionality. In other words, the image with 3D will be converted into 2D. While in the image resize phase, the dimensionality of all images will be resized into (128×128) dimensions. Subsequently, the output of the pre-processing step will be fed into CNN.

2.3. Convolutional neural network

The convolutional and classifier are the main two bases of the architectures of the CNN. The base of convolutional includes three main layer types which are: convolutional, activation, and pooling layers. The three layers are used to found out the input images' critical features that named maps of the features. Whilst the base of the classifier includes the dense layers which convert the maps of the features into vectors with one dimension to speed up the classification mission utilizing a number of neurons [33]. This study proposes a CNN with fifteen layers for detecting the COVID-19 using X-ray images. Figure 2 presents the full detailed diagram of the proposed CNN. The input layer has a shape of (128×128×1). The proposed model has three convolutional layers, two max pooling layers, and one fully connected layer. The first convolutional layer has eight filters of size (3×3), with one a same padding and a stride followed by batch normalization and rectified linear units (ReLU) layers. The second and third convolutional layers have 16 and 32 filters of size (3×3), respectively. Both layers have one a same padding and a stride as well as both are followed by batch normalization and ReLU layers. The two max pooling layers with a size of two and a stride of two, both follow first and second convolutional layers. The output of these layers is flattened and fed into a fully connected layer followed by softmax layer. The final output layer refers to a binary classification. Table 2 illustrates the parameters of the trained CNN model utilized for detecting COVID-19.



	Name	Type	Activations	Learnables
1	imageinput 128x128x1 images with 'zerocenter' normalization	Image Input	128×128×1	-
2	conv_1 8 3x3x1 convolutions with stride [1 1] and padding 'same'	Convolution	128×128×8	Weights 3×3×1×8 Bias 1×1×8
3	batchnorm_1 Batch normalization with 8 channels	Batch Normalization	128×128×8	Offset 1×1×8 Scale 1×1×8
4	relu_1 ReLU	ReLU	128×128×8	-
5	maxpool_1 2x2 max pooling with stride [2 2] and padding [0 0 0 0]	Max Pooling	64×64×8	-
6	conv_2 16 3x3x8 convolutions with stride [1 1] and padding 'same'	Convolution	64×64×16	Weights 3×3×8×16 Bias 1×1×16
7	batchnorm_2 Batch normalization with 16 channels	Batch Normalization	64×64×16	Offset 1×1×16 Scale 1×1×16
8	relu_2 ReLU	ReLU	64×64×16	-
9	maxpool_2 2x2 max pooling with stride [2 2] and padding [0 0 0 0]	Max Pooling	32×32×16	-
10	conv_3 32 3x3x16 convolutions with stride [1 1] and padding 'same'	Convolution	32×32×32	Weights 3×3×16×32 Bias 1×1×32
11	batchnorm_3 Batch normalization with 32 channels	Batch Normalization	32×32×32	Offset 1×1×32 Scale 1×1×32
12	relu_3 ReLU	ReLU	32×32×32	-
13	fc 2 fully connected layer	Fully Connected	1×1×2	Weights 2×32768 Bias 2×1
14	softmax softmax	Softmax	1×1×2	-
15	classoutput crossentropyex with classes '1' and '2'	Classification Output	-	-

Figure 2. The diagram of the proposed CNN

Table 2. Parameters of the trained model utilized for detecting COVID-19

Parameter	Value
Method of Optimisation	SGDM
Learning Rate	1.0000e-03
Max Epochs	10
Shuffle	every-epoch
Frequency Validation	30
Momentum	0.9000
Mini Batch Size	128

3. RESULTS AND DISCUSSION

Our proposed model is intended to the detection of COVID-19 by using CNN algorithm based on X-ray images for distinguishing healthy people from patients who are infected with COVID-19. In this work, the images database has been divided into 60% for the training process and 40% for the testing process. Furthermore, the proposed model has been performed by using MATLAB R2019a as a simulation tool over a PC using Windows 10, 8 GB RAM, and Intel Core-i5, 3.00 GHz CPU. Also, there are different evaluation measurements have been used in order to evaluate the performance of the proposed model with respect to the effectiveness in the detection of COVID-19. These evaluation measurements are accuracy, precision, specificity, sensitivity, negative prediction value (NPV), F-measure, and G-mean. Further, these measurements have been calculated as shown in (1)-(7) [34]–[36].

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$\text{Precision} = \frac{TP}{TP + FP} \quad (2)$$

$$\text{Specificity} = \frac{TN}{TN + FP} \quad (3)$$

$$\text{Sensitivity} = \frac{TP}{TP + FN} \quad (4)$$

$$\text{NPV} = \frac{TN}{TN + FN} \quad (5)$$

$$\text{F} - \text{measure} = \frac{2 \times Precision \times Recall}{Recall + Precision} \quad (6)$$

$$\text{G} - \text{Mean} = \sqrt[2]{\text{Specificity} \times \text{Recall}} \quad (7)$$

Where, TP refers to true positive, TN refers to true negative, FP and FN denote to false positive and false negative, respectively. Table 3 shows the achieved results of the proposed model in the detection of COVID-19.

Table 3. The achieved results of the proposed model

Accuracy	Precision	Specificity	Sensitivity	NPV	F-Measure	G-mean
98.68	100.00	100.00	97.37	97.44	98.67	98.68

According to the experimental results which have shown in Figure 3, the proposed model has presented promising results for detecting COVID-19, where the proposed CNN has achieved the highest accuracy that reached to 98.68%. In addition, the proposed model has gained 100.00% for both precision and specificity. While the obtained results for the measurements of sensitivity, NPV, and F-measure were 97.37%, 97.44%, and 98.67%, respectively. Based on the obtained results, the proposed model using the CNN algorithm is able to perform effectively in the detection of COVID-19 based on X-ray images. Besides, Figure 3 shows the confusion matrix of the proposed model.

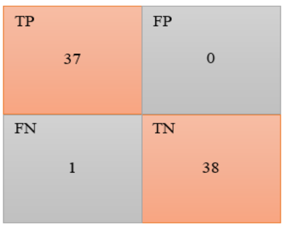


Figure 3. The confusion matrix

Additionally, Figure 4 shows the achieved accuracy and the loss percentage for the training process and the validation process in each iteration of the experiment. The proposed model has been evaluated also in terms of receiver operating characteristic (ROC), where it has obtained 0.98684 of ROC as shown in Figure 5.

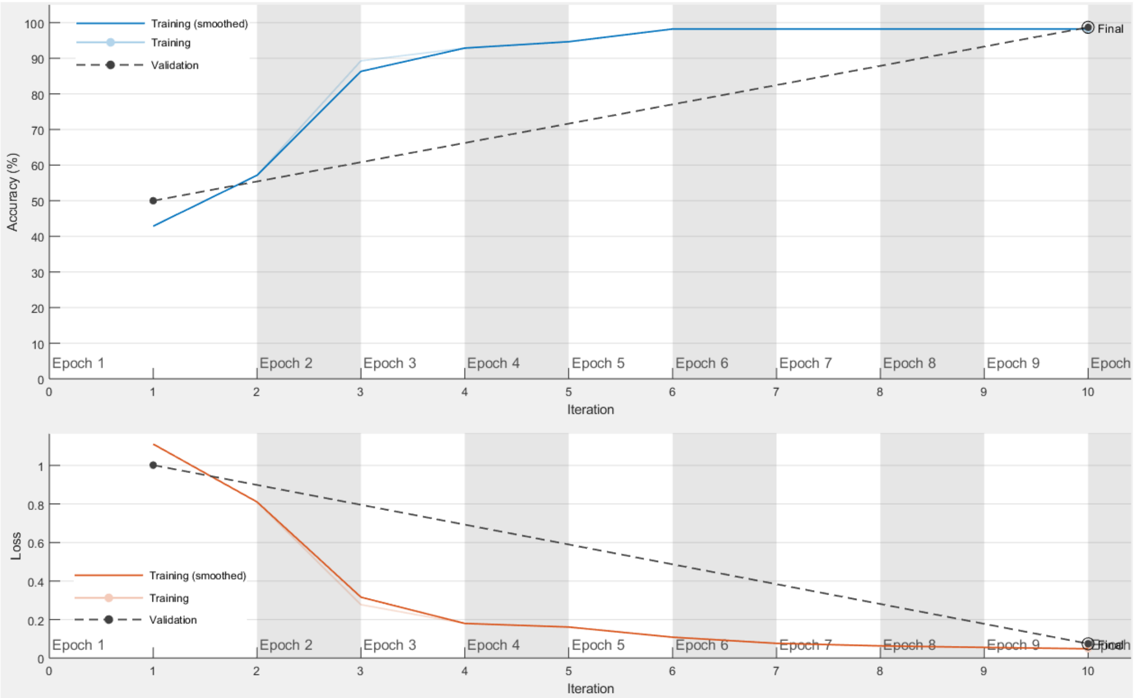


Figure 4. The achieved accuracy and the loss percentage for the training and validation processes

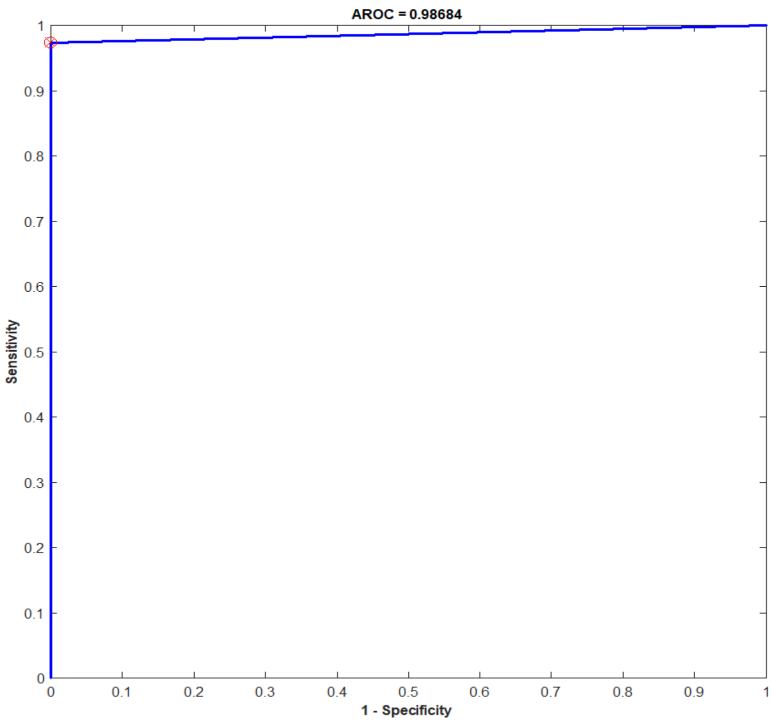


Figure 5. The ROC result for CNN model

Furthermore, the performance of the proposed model using the CNN algorithm has been compared with other recent methods [25], [32], [37]–[40] in terms of accuracy in the detection of COVID-19. All these methods have been presented with different deep learning models and different machine learning algorithms for detecting patients who are infected by COVID-19 based on X-ray images. The performance of the proposed model has outperformed all its comparatives in terms of the accuracy measurement. Table 4 shows the comparison between methods with respect to the accuracy in the detection of COVID-19.

Table 4. The comparison between methods

Method	Accuracy
Method in [25]	90.00
Method in [37]	95.12
Method in [38]	98.00
Method in [39]	94.10
Method in [40]	97.48
Method in [32]	95.38
Our method	98.68

4. CONCLUSION

The COVID-19 outbreak has made the whole world in a difficult situation causing the life in many countries to a frightening halt and claiming thousands of lives. On the other hand, deep learning algorithms have been widely used in the analysis of radiological images. In addition, these algorithms have been proved their effectiveness in the classification process. Therefore, this paper has presented the CNN model of deep learning algorithms for the detection of COVID-19 based on chest X-ray images. The database of X-ray images is overcome the CT images in terms of time consumption and cost. In the proposed model, there were 94% samples for the healthy class and 94% samples for patients who are suffering from COVID-19. Based on the experimental results, the proposed model has obtained 98.68% accuracy, 100% precision, 100% specificity, 97.37% sensitivity, 98.67% F-measure. Furthermore, the achieved results of G-mean, NPV, and ROC were 98.68%, 97.44%, and 0.98684, respectively. According to the obtained results, the proposed model can achieve encouraging detection accuracy for COVID-19 from X-ray images. In future work, we aim to apply the proposed model of deep learning for COVID-19 detection based on the large database of image samples. Another future work can include using machine learning algorithms for detecting COVID-19.

REFERENCES

[1] C. Huang *et al.*, "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China," *The Lancet*, vol. 395, no. 10223, pp. 497–506, Feb. 2020, doi: 10.1016/S0140-6736(20)30183-5.

[2] WHO web sasıyfa, "Pneumonia of unknown cause–China," *Disease outbreak news*, Accessed 20 July, 2021: http://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/%0Ahttps://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/

[3] T. Singhal, "A review of coronavirus disease-2019 (COVID-19)," *Indian Journal of Pediatrics*, vol. 87, no. 4, pp. 281–286, Mar. 2020, doi: 10.1007/s12098-020-03263-6.

[4] W. Wang *et al.*, "Detection of SARS-CoV-2 in different types of clinical specimens," *JAMA - Journal of the American Medical Association*, vol. 323, no. 18, pp. 1843–1844, Mar. 2020, doi: 10.1001/jama.2020.3786.

[5] Y. Pathak, P. K. Shukla, A. Tiwari, S. Stalin, and S. Singh, "Deep transfer learning based classification model for COVID-19 disease," *Irbm*, May 2020, doi: 10.1016/j.irbm.2020.05.003.

[6] X. Xie, Z. Zhong, W. Zhao, C. Zheng, F. Wang, and J. Liu, "Chest CT for typical coronavirus disease 2019 (COVID-19) pneumonia: relationship to negative RT-PCR Testing," *Radiology*, vol. 296, no. 2, pp. E41–E45, Aug. 2020, doi: 10.1148/radiol.2020200343.

[7] D. Singh, V. Kumar, Vaishali, and M. Kaur, "Classification of COVID-19 patients from chest CT images using multi-objective differential evolution–based convolutional neural networks," *European Journal of Clinical Microbiology and Infectious Diseases*, vol. 39, no. 7, pp. 1379–1389, Apr. 2020, doi: 10.1007/s10096-020-03901-z.

[8] H. S. Basavegowda and G. Dagnew, "Deep learning approach for microarray cancer data classification," *CAAI Transactions on Intelligence Technology*, vol. 5, no. 1, pp. 22–33, Jan. 2020, doi: 10.1049/trit.2019.0028.

[9] M. A. A. Albadr, S. Tiun, M. Ayob, F. T. Al-Dhief, K. Omar, and F. A. Hamzah, "Optimised genetic algorithm-extreme learning machine approach for automatic COVID-19 detection," *PLoS ONE*, vol. 15, no. 12, p. e0242899, Dec. 2020, doi: 10.1371/journal.pone.0242899.

[10] M. Albadr, S. Tiun, and F. Al-Dhief, "Evaluation of machine translation systems and related procedures," *Journal of Engineering and Applied Sciences*, vol. 13, pp. 3961–3972, 2018.

[11] M. Albadr and S. Tiuna, "Extreme learning machine: a review," *International Journal of Applied Engineering Research*, vol. 12, pp. 4610–4623, 2017.

[12] M. A. A. Albadr, S. Tiun, F. T. AL-Dhief, and M. A. M. Sammour, "Spoken language identification based on the enhanced self-adjusting extreme learning machine approach," *PLoS ONE*, vol. 13, no. 4, p. e0194770, Apr. 2018, doi: 10.1371/journal.pone.0194770.

[13] M. A. A. Albadr, S. Tiun, M. Ayob, and F. T. AL-Dhief, "Spoken language identification based on optimised genetic algorithm–extreme learning machine approach," *International Journal of Speech Technology*, vol. 22, no. 3, pp. 711–727, Jul. 2019, doi: 10.1007/s10772-019-09621-w.

[14] M. A. Abbood Albadr, S. Tiun, M. Ayob, F. T. Al-Dhief, T. A. N. Abdali, and A. F. Abbas, "Extreme learning machine for automatic language identification utilizing emotion speech data," *2021 International Conference on Electrical, Communication, and Computer Engineering (ICECCE)*, Jun. 2021, doi: 10.1109/ICECCE52056.2021.9514107.

[15] F. T. Al-Dhief *et al.*, "Voice pathology detection and classification by adopting online sequential extreme learning machine," *IEEE Access*, vol. 9, pp. 77293–77306, 2021, doi: 10.1109/ACCESS.2021.3082565.

[16] O. Ibrahim Obaid, M. Mohammed, M. K. Abd Ghani, S. Mostafa, and F. Al-Dhief, "Evaluating the performance of machine learning techniques in the classification of wisconsin breast cancer," *International Journal of Engineering and Technology*, vol. 7, pp. 160–166, 2018, doi: 10.14419/ijet.v7i4.36.23737.

[17] M. A. Mohammed *et al.*, "An anti-spam detection model for emails of multi-natural language," *Journal of Southwest Jiaotong University*, vol. 54, no. 3, Jun. 2019, doi: 10.35741/issn.0258-2724.54.3.6.

[18] A. F. Abbas, U. U. Sheikh, F. T. Al-Dhief, and M. N. H. Mohd, "A comprehensive review of vehicle detection using computer vision," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 19, no. 3, pp. 838–850, Jun. 2021, doi: 10.12928/TELKOMNIKA.v19i3.12880.

[19] M. H. H. Khairi *et al.*, "Detection and classification of conflict flows in SDN using machine learning algorithms," *IEEE Access*, vol. 9, pp. 76024–76037, 2021, doi: 10.1109/ACCESS.2021.3081629.

[20] F. T. Al-Dhief *et al.*, "Voice pathology detection using machine learning technique," in *2020 IEEE 5th International Symposium on Telecommunication Technologies, ISTT 2020 - Proceedings*, Nov. 2020, pp. 99–104, doi: 10.1109/ISTT50966.2020.9279346.

[21] F. T. Al-Dhief *et al.*, "A survey of voice pathology surveillance systems based on internet of things and machine learning algorithms," *IEEE Access*, vol. 8, pp. 64514–64533, 2020, doi: 10.1109/ACCESS.2020.2984925.

[22] F. T. AL-Dhief, N. M. A. Latiff, M. M. Baki, N. N. N. A. Malik, N. Sabri, and M. A. A. Albadr, "Voice pathology detection using support vector machine based on different number of voice signals," in *2021 26th IEEE Asia-Pacific Conference on Communications (APCC)*, Oct. 2021, pp. 1–6, doi: 10.1109/apcc49754.2021.9609830.

[23] M. A. Mohammed *et al.*, "Voice pathology detection and classification using convolutional neural network model," *Applied Sciences (Switzerland)*, vol. 10, no. 11, p. 3723, May 2020, doi: 10.3390/app10113723.

[24] T. B. Chandra, K. Verma, B. K. Singh, D. Jain, and S. S. Netam, "Coronavirus disease (COVID-19) detection in chest X-Ray images using majority voting based classifier ensemble," *Expert Systems with Applications*, vol. 165, p. 113909, Mar. 2021, doi: 10.1016/j.eswa.2020.113909.

[25] E. E.-D. Hemdan, M. A. Shouman, and M. E. Karar, "COVIDX-Net: A framework of deep learning classifiers to diagnose COVID-19 in X-ray images," Mar. 2020, [Online]. Available: http://arxiv.org/abs/2003.11055.

[26] L. Brunese, F. Mercaldo, A. Reginelli, and A. Santone, "Explainable deep learning for pulmonary disease and coronavirus COVID-19 detection from X-rays," *Computer Methods and Programs in Biomedicine*, vol. 196, p. 105608, Nov. 2020, doi: 10.1016/j.cmpb.2020.105608.

[27] J. P. Cohen, P. Morrison, L. Dao, K. Roth, T. Q. Duong, and M. Ghassemi, "COVID-19 image data collection: prospective predictions are the future," Jun. 2020, [Online]. Available: http://arxiv.org/abs/2006.11988.

[28] C. Le Van, V. Puri, N. T. Thao, and D. N. Le, "Detecting lumbar implant and diagnosing scoliosis from vietnamese x-ray imaging using the pre-trained api models and transfer learning," *Computers, Materials and Continua*, vol. 66, no. 1, pp. 17–33, 2021, doi: 10.32604/cmc.2020.013125.

[29] S. H. Yoo *et al.*, "Deep learning-based decision-tree classifier for COVID-19 diagnosis from chest X-ray imaging," *Frontiers in Medicine*, vol. 7, Jul. 2020, doi: 10.3389/fmed.2020.00427.

[30] P. Afshar, S. Heidarian, F. Naderkhani, A. Oikonomou, K. N. Plataniotis, and A. Mohammadi, "COVID-CAPS: A capsule network-based framework for identification of COVID-19 cases from X-ray images," *Pattern Recognition Letters*, vol. 138, pp. 638–643, Oct. 2020, doi: 10.1016/j.patrec.2020.09.010.

[31] M. E. H. Chowdhury *et al.*, "Can ai help in screening viral and COVID-19 pneumonia?," *IEEE Access*, Mar. 2020, doi: 10.1109/ACCESS.2020.3010287.

[32] P. K. Sethy, S. K. Behera, P. K. Ratha, and P. Biswas, "Detection of coronavirus disease (COVID-19) based on deep features and support vector machine," *International Journal of Mathematical, Engineering and Management Sciences*, vol. 5, no. 4, pp. 643–651, Aug. 2020, doi: 10.33889/IJMEMS.2020.5.4.052.

[33] Y. Sun, B. Xue, M. Zhang, G. G. Yen, and J. Lv, "Automatically designing CNN architectures using the genetic algorithm for image classification," *IEEE Transactions on Cybernetics*, vol. 50, no. 9, pp. 3840–3854, Sep. 2020, doi: 10.1109/TCYB.2020.2983860.

[34] M. A. Albadr, S. Tiun, M. Ayob, and F. Al-Dhief, "Genetic algorithm based on natural selection theory for optimization problems," *Symmetry*, vol. 12, no. 11, pp. 1–31, Oct. 2020, doi: 10.3390/sym12111758.

[35] M. A. A. Albadr and S. Tiun, "Spoken language identification based on particle swarm optimisation–extreme learning machine approach," *Circuits, Systems, and Signal Processing*, vol. 39, no. 9, pp. 4596–4622, Mar. 2020, doi: 10.1007/s00034-020-01388-9.

[36] M. A. A. Albadr, S. Tiun, M. Ayob, M. Mohammed, and F. T. AL-Dhief, "Mel-frequency cepstral coefficient features based on standard deviation and principal component analysis for language identification systems," *Cognitive Computation*, vol. 13, no. 5, pp. 1136–1153, Jul. 2021, doi: 10.1007/s12559-021-09914-w.

[37] A. Abbas, M. M. Abdelsamea, and M. M. Gaber, "Classification of COVID-19 in chest X-ray images using DeTraC deep convolutional neural network," *Applied Intelligence*, vol. 51, no. 2, pp. 854–864, Sep. 2021, doi: 10.1007/s10489-020-01829-7.

[38] D. Ezzat, A. ell Hassanien, and H. A. Ella, "GSA-DenseNet121-COVID-19: a Hybrid deep learning architecture for the diagnosis of COVID-19 disease based on gravitational search optimization algorithm," *Applied Soft Computing*, Apr. 2020, doi: 10.1016/j.asoc.2020.106742.

[39] H. Maghdid, A. T. Asaad, K. Z. G. Ghafoor, A. S. Sadiq, S. Mirjalili, and M. K. K. Khan, "Diagnosing COVID-19 pneumonia from x-ray and CT images using deep learning and transfer learning algorithms," in *Multimodal Image Exploitation and Learning 2021*, Apr. 2021, p. 26, doi: 10.1117/12.2588672.

[40] L. N. Mahdy, K. A. Ezzat, H. H. Elmousalami, H. A. Ella, and A. E. Hassanien, "Automatic X-ray COVID-19 lung image classification system based on multi-level thresholding and support vector machine," *medRxiv*, Apr. 2020, doi: 10.1101/2020.03.30.20047787.

BIOGRAPHIES OF AUTHORS

Essam Hammodi Ahmed is received the B.S. degree in Information Systems of Computer sciences and information ethnology from the University of Technology/Computer sciences College in 2003 and the M.S. degree in Computer Networks from Sydney University, Computer Engineering College, Sydney Australia in 2011, and and Ph.D. degrees in Computer Networks, currently working as a Lecturer in Faculty of Computing Technical engineering, College of Information Technology, Imam Ja'afar Al-Sadiq University, Al-Muthanna 66002, Iraq. He can be contacted at email: essamimc@yahoo.com.

Majid Razaq Mohamed Alsemawi He was born in Samawah, Iraq in 1968. He received a degree bachelor of engineering in Communications and networks Computer from Middlesex University in Britain in 2011. And also, he has got a master degree in Telecommunication from Middlesex University in Britain in 2013. He can be contacted at email: Zh330551@gmail.com.

Mohammed Hasan Mutar received the B.S. degree in communication engineering from Al-Furat Al-Awsat Technical University/Engineering Technical College of Al-Najaf, in 2009 and the M.S. degree in digital system and computer electronics (DSCE) from Jawaharlal Nehru Technological University Hyderabad (JNTU), Hyderabad, India, in 2013. Where he is currently working Head of Department Computer Technical engineering, College of Information Technology, Imam Ja'afar Al-Sadiq University, Al-Muthanna 66002, Iraq. He can be contacted at email: Moh2007hmf@gmail.com.

Hatem Oday Hanoosh was born in samawah, Iraq, in 1991. He received the B.S in computer techniques engineering in 2014-2015 from Islamic University College in Najaf city. and M.S. degrees in electronic engineering (telecommunication system) from university technical Malaysia Melaka (UTEM), Malaysia, in 2018, respectively, and he studies the Ph.D. degree in electronic engineering in university technology Malaysia (UTM) in Johor Bahru city, His current research interests include millimeter-wave antennas, base station antennas, and waveguide slot antennas. He can be contacted at email: hatem.oday@sadiq.edu.iq.

Ali Hashem Abbas received the B.S. degree in communication engineering from Al-Furat Al-Awsat Technical University/ Engineering Technical College of Al-Najaf, in 2010 and the M.S. degree in digital system and computer electronics (DSCE) from Jawaharlal Nehru Technological University Hyderabad (JNTU), Hyderabad, India, in 2014, and Ph.D. degrees in Communication Engineering, Clustering of Vehicular Ad-Hoc Networks (VANETs) from UTHM University Tun Hussein Onn Malaysia, Johor, Malaysia, in 2019. Where he is currently working Head of Department of Scientific Affairs and Promotions at the Department of Computer Technical engineering, College of Information Technology, Imam Ja'afar Al-Sadiq University, Al-Muthanna 66002, Iraq. His research interests are cluster stability for intervehicle communication and distributed algorithms, for vehicular ad hoc networks. In addition, He is a reviewer for leading communication, and computer networks engineering journals such as vehicular ad hoc networks, vehicular communications, wireless communication, IEEE Wireless Communications Letters, Journal of Sensors, and IEEE Access Journal. He can be contacted at email: alsalamy1987@gmail.com.