Multimedia Tools and Applications
https://doi.org/10.1007/s11042-022-12952-7

Automatic COVID-19 detection mechanisms and approaches from medical images: a systematic review

Amir Masoud Rahmani · Elham Azhir · Morteza Naserbakht · Mokhtar Mohammadi · Adil Hussein Mohammed Aldalwie · Mohammed Kamal Majeed, et al. ***[full author details at the end of the article]***

Received: 19 January 2021 / Revised: 9 May 2021 / Accepted: 10 March 2022
Published online: 31 March 2022

Abstract
Since early 2020, Coronavirus Disease 2019 (COVID-19) has spread widely around the world. COVID-19 infects the lungs, leading to breathing difficulties. Early detection of COVID-19 is important for the prevention and treatment of pandemic. Numerous sources of medical images (e.g., Chest X-Rays (CXR), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI)) are regarded as a desirable technique for diagnosing COVID-19 cases. Medical images of coronavirus patients show that the lungs are filled with sticky mucus that prevents them from inhaling. Today, Artificial Intelligence (AI) based algorithms have made a significant shift in the computer aided diagnosis due to their effective feature extraction capabilities. In this survey, a complete and systematic review of the application of Machine Learning (ML) methods for the detection of COVID-19 is presented, focused on works that used medical images. We aimed to evaluate various ML-based techniques in detecting COVID-19 using medical imaging. A total of 26 papers were extracted from ACM, ScienceDirect, Springerlink, Tech Science Press, and IEEExplore. Five different ML categories to review these mechanisms are considered, which are supervised learning-based, deep learning-based, active learning-based, transfer learning-based, and evolutionary learning-based mechanisms. A number of articles are investigated in each group. Also, some directions for further research are discussed to improve the detection of COVID-19 using ML techniques in the future. In most articles, deep learning is used as the ML method. Also, most of the researchers used CXR images to diagnose COVID-19. Most articles reported accuracy of the models to evaluate model performance. The accuracy of the studied models ranged from 0.84 to 0.99. The studies demonstrated the current status of AI techniques in using AI potentials in the fight against COVID-19.

Keywords COVID-19 · Medical image · Artificial intelligence · Machine learning · Literature review

1 Introduction

Coronavirus Disease 2019 (COVID-19) is a transmissible disease that has spread rapidly across the world. According to the World Health Organization (WHO), fever, cough, and respiratory problems are the most common symptoms of COVID-19 [22]. The Reverse-Transcription Polymerase Chain Reaction (RT-PCR) is typically used as the standard test for screening suspected cases of coronavirus [41]. Nevertheless, there are recent reports about the ineffectiveness of the RT-PCR test, compared to medical imaging (e.g., X-ray, CT scans), which can rapidly diagnose COVID-19 [8]. COVID-19 detection methods using RT-PCR test are very costly and time consuming. In addition, because of the high false positive rate of RT-PCR, many patients had to be tested several times. Medical lung images can efficiently detect coronavirus in patients before a blood test. Therefore, the acquisition of medical images have a significant role in the suitable stages of treatment in the fight against the pandemic of coronavirus [34]. However, medical experts efficiency and accuracy, are some major challenges for the diagnosis of COVID-19 using medical imaging. This will be highlighted especially in pandemic situations in which experts are under stress. Therefore, automated analysis of medical images can provide faster and more accurate diagnosis of lung abnormalities.

The application of Artificial Intelligence (AI) techniques has increased in various domains [27], particularly in medicine [12, 26, 35, 52]. Compared to traditional methods, AI is used to achieve more accurate results in less time [7]. For instance, Abbas, Abdelsamea [1] developed an entrance control system based on human facial recognition. According to the results, recognition accuracy of 97.27% is achieved on an E-face dataset, with a 5.26 Frames Per Second (FPS) processing speed. Machine learning (ML) is a subfield of AI. Various ML-based techniques have been proposed by several researchers to diagnose COVID-19 from medical images. The application of ML-based methods in the analysis of COVID-19 medical images reduces the number of false-positive and negative diagnoses and provides rapid diagnostic services to patients. Although ML-based methods can be useful in diagnosing COVID-19, choosing the suitable ML method that can produce accurate results is challenging. In addition, low accuracy and computational efficiency are some difficulties associated with these methods. The wide range of ML techniques makes it difficult to select them for the detection of COVID-19, especially when no specific ML technique is far superior to the other methods. The existence of numerous evaluation criteria and the conflict among them make it difficult to evaluate and compare these techniques and increase the challenge.

Several studies have been performed based on ML techniques in the diagnosis of COVID-19 using medical imaging. The assessment of the application of ML in the diagnostic imaging of patients with COVID-19 could provide useful information on the type and size of the dataset and the suitable use of ML. Thus, the current survey aims to systematically investigate the research efforts of emerging COVID-19 medical image detection technologies based on the ML technique. In this survey, the existing research on automated COVID-19 detection techniques is categorized into five major groups, including supervised learning-based, deep learning-based, active learning-based, transfer learning-based, and evolutionary learning-based mechanisms. These techniques will be described in detail together with the strengths and weaknesses of every technique. Also, we compare the differences between the mentioned techniques, and provides some solutions for the future studies. Four major contributions of this survey are as follows:

1. Classifying and reviewing ML-based techniques for COVID-19 detection from medical images in five main categories, and reviewing their main advantages and weaknesses.
2. Providing a summary of the selected papers.
3. Providing an assessment using accuracy metric.

4. Discussing the key areas where future research can enhance the application of ML in the medical diagnosis field.

The following classification will be discussed in the rest of the paper. The previous researches have been provided in Section 2. The article selection process is presented in Section 3. Section 4 investigates the relevant papers in automatic COVID-19 detection using medical images. The reviewed methods are compared in section 5. Section 6 discusses the future work and open issues. Finally, the conclusion part is presented in Section 7.

2 Related work

This section reviews some of the relevant automatic COVID-19 detection surveys to determine the need for this paper.

Albahri, Zaidan [7] systematically reviewed the AI methods used to diagnose COVID-19 from medical images. Henceforth, 11 articles were classified into two main groups including review and research studies. The authors addressed the research studies based on types of classification (i.e. binary, multi-class, multi-labelled and hierarchical classifications). According to the investigations, the procedure of evaluating AI methods used to classify COVID-19 medical images is a multi-complex attribute problem. The authors concluded that the use of Multi-Criteria Decision Analysis (MCDA) is an effective method to deal with the complexity of the problem. The authors proposed a detailed MCDA technique for the evaluation of AI methods applied in COVID-19 medical image classification. Also, a comprehensive study to identify the challenges of the given subject in academic literature has been performed in this paper. Although, there are some gaps in reviewing a wide variety of AI method used for COVID-19 diagnosis from medical images. In addition, only 11 papers were discussed in this paper and open issues have not been well described.

Recently, many studies have focused on statistical and AI-driven analysis of COVID-19 data. These studies require that the data presented for analysis should be available for the development and validation of the works. Shuja, Alanazi [50] reviewed research works based on open-source data and code. The suggested taxonomy categorizes the reviewed articles in terms of application and data type. Diagnosis of COVID-19 from medical images, cough based detection of COVID-19, transmission prediction using COVID-19 case reports, and social media sentiment analysis on COVID-19 [6] are some main categories of the presented survey. The authors also discussed some future research directions for data-driven COVID-19. However, this paper has written in a non-systematic way and an AI-based taxonomy has not been investigated. Also, only few papers were discussed for medical image datasets.

Ozsahin, Sekeroglu [42] reviewed articles that used AI methods to detect COVID-19 by chest CT scan. The existing research in automated COVID-19 detection is categorized based on the classification results: COVID-19/normal, COVID-19/non-COVID-19, COVID-19/non-COVID-19 pneumonia, and severity. Various qualitative parameters are also investigated in this paper. However, the article selection mechanism is not provided. In addition, future works is not properly described.

Adly, Adly [4] reviewed the current literature on using AI techniques for COVID-19 prevention and control. The authors identified 10 of the latest approaches based on AI to prevent the spread of COVID-19. These approaches include: (1) diagnosis of suspected COVID-19 cases, (2) large-scale screening of COVID-19, (3) monitoring, (4) interactions with experimental therapies, (5) screening for pneumonia, (6) data collection and integration using Internet of Intelligent Things (IIoT) [3], (7) resource allocation, (8) predictions, (9) simulation, and (10) robotics for medical quarantine. However, few studies were addressed in some categories of their survey and the mechanism of choosing studies should be at the center of attention. Although, they have not reviewed the effectiveness of the algorithms. Furthermore, open issues are not well described.

Lalmuanawma, Hussain [32] presented a complete review of the applications of ML and AI techniques on COVID-19. Five groups are introduced for studying selected techniques, which include COVID-19 screening, predicting, forecasting, tracking, and drug development using AI and ML techniques. The challenges of exploiting these techniques in real-world problems have also been considered. However, there is no clear method for article selection. Additionally, future works are not properly described.

Vaishya, Javaid [53] reviewed the use of AI to prevent and fight with COVID-19. Seven major AI applications for COVID-19 pandemic are reviewed, including diagnosis of the disease, patient monitoring, contact tracing, forecasting cases and deaths, production of drugs, workload reduction, and disease prevention. However, few papers are reviewed and the article selection mechanism is not provided. Furthermore, a detailed AI-based taxonomy is not provided and the qualitative parameters are not investigated.

Kannan, Subbaram [29] studies the use of AI in discovering vaccines/drugs. The authors suggested that AI could be useful in vaccine discovery by analyzing the virus's capabilities, virulence, and genome. This survey combined discussions of deep learning–based drug screening for predicting the interaction between protein and ligands, and using imaging results linked to AI tools for detecting SARS-CoV-2 infections. However, only a few papers were discussed in this paper and the discussed applications of AI are not reviewed in adequate detail. This paper does not include the disadvantages and advantages of different methods. Also, future works and open issues have not been described.

Mohammed, Abdulkareem [38] introduced a framework for assessing the performance of COVID-19 ML models. This framework can be useful in choosing the optimal classifier for the detection of COVID-19. A Multi-Criteria Decision-Making (MCDM) technique developed based on SARS-CoV-2 diagnostic ML models and various evaluation criteria including, precision, accuracy, recall, AUC point, time consumption, and four binary classification errors (TF, TN, FP, and FN). As a result, the Support Vector Machines (SVM) classifier obtained the best performance followed by Naive Bayes (NB), and Radial Basis Function network (RBF). The taxonomy and comparison of the studied methods are presented. Although, this paper is not a systematic literature review.

Mohammed, Abdulkareem [39] evaluated different ML techniques (e.g., Artificial Neural Networks (ANNs), SVM, RBF, K-Nearest Neighbors (KNN), Decision Tree (DT), and CN2 rule inducer) and deep learning models (e.g., MobileNets V2, ResNet50, GoogleNet, DarkNet, and Xception) to identify COVID-19 infected individuals using X-ray images. A large X-ray dataset (400 normal cases, and 400 COVID cases) is developed. Based on the trial results, ResNet50 model achieved the best accuracy of 98.8%. Furthermore, in traditional ML techniques, the SVM achieved the best outcomes with 95% accuracy and RBF with 94% accuracy. However, this survey has not papers selection mechanism.

Recently, Chen, Li [18] presented a complete survey on applications of AI in fighting against COVID-19, including disease detection, virology and pathogenesis, drug development, and epidemic prediction. The authors divided the diagnosing models into two categories: CT-based models and X-ray-based models, and present representative architecture for each of them. The representative architecture of CT-based models involves image segmentation, feature extraction, and classification and prediction, while the representative architecture of X-ray-based models involves model pre-training, fine-tuning, and prediction. But some X-ray-based models also consist of image segmentation and feature extraction process, and some CT-based models also consist of transfer learning process. However, this survey did not provide a systematic literature review. Also, there is no detailed taxonomy for AI-driven techniques in COVID-19 diagnosis using medical imaging.

Bhattacharya, Maddikunta [13] studied deep learning-based methods used for diagnosis of COVID-19 pandemic. The survey also addresses issues related to the implementation of deep learning in COVID-19 medical image processing, including lack of reliable and sufficient data. Like previous study, there is no detailed taxonomy for AI-driven techniques in COVID-19 diagnosis using medical imaging. Also, this paper did not provide a systematic literature review.

Shi, Wang [49] reviewed various deep learning studies on CXR and CT scans to detect COVID-19. The review is divided into three sections including, medical imaging, image segmentation and diagnosis. However, there is no detailed taxonomy for AI-driven techniques in COVID-19 diagnosis. Also, this survey is written non-systematically.

Dong, Tang [19] reviewed the imaging and computational techniques used to detect COVID-19. The quantitative analysis of imaging data (e.g., CT, Positron Emission Tomography-CT (PET/CT), lung ultrasound, Magnetic Resonance Imaging (MRI)) using AI is explored in this paper. Like previous, this paper has written non-systematically and there is no detailed taxonomy for AI-driven techniques.

Due to the reviewed studies, there are some weaknesses in the current automated COVID-19 detection techniques as follows:

- Many articles did not provide any reasonable classification of COVID-19 detection methods from medical images using AI techniques.
- Some papers did not asses the qualitative metrics for investigating the techniques.
- Many articles did not clear the article selection mechanism.
- Some papers did not discuss the future challenges of automatic COVID-19 detection mechanisms.

The reasons mentioned led us to write a survey paper on COVID-19 detection from medical images using ML mechanisms to overcome all of these lacks.

3 Systematic review

A systematic literature review (SLR) is the investigation of research efforts that relate to a specific topic [31]. It contains an explanation of the findings of a set of studies. A systematic review ensures that more reliable results are achieved. In this paper, an SLR is used to conduct a complete study of the ML-based medical image analyses. In the following, we presented the article selection process.

In the first stage, Google Scholar and electronic databases such as ACM, ScienceDirect, Springerlink, Tech Science Press, and IEEExplore are used to find the primary studies based on the keyword search. Nine terms (artificial intelligence, machine learning, deep learning, neural networks, computational intelligence, COVID-19, coronavirus, medical images, and chest CT) are used to discover suitable researches in these databases. Therefore, 890 articles found for re-evaluation. In the next stage, the articles selected based on title and publisher, including Elsevier, ACM, Springer, IEEE, and Tech Science Press. In total, 100 articles are selected from the reputed journals and conference papers. Finally, the authors read the full text of the abstracts to evaluate the relevance of the articles. Based on the article's relevance, 74 articles are excluded. Therefore, 26 studies were selected for further analysis in section 4.

The distribution of the articles by different publishers is shown in Fig. 1. The highest number of articles is related to Elsevier with 11 articles (42%) and the lowest number of articles is related to Tech Science Press with one article (4%).

4 A review of the selected AI-driven COVID-19 detection from medical images mechanisms

The development of conventional machine learning has improved the capabilities of AI applications to deal with various aspects of COVID-19. This article presents five different categories of machine learning algorithms for the reviewed articles based on the learning styles. These categories are supervised learning-based, deep learning-based, active learning-based, transfer learning-based, and evolutionary learning-based mechanisms.

Generally, 26 articles will be reviewed during this section. The selected mechanisms regarding supervised learning-based are discussed in Section 4.1, deep learning-based are discussed in Section 4.2, active learning-based are discussed in Section 4.3, transfer learning-based are discussed in Section 4.4, and evolutionary learning-based are discussed in Section 4.5. Also, their basic technique properties, as well as their benefits and drawbacks will be discussed. Figure 2 indicates the taxonomy of the ML-based COVID-19 detection from medical images techniques.

4.1 Supervised learning-based

The supervised learning algorithm uses a basis labeled dataset to predict the correct label of other unlabeled data. As shown in Fig. 3, the relation between a set of inputs and outputs is found while training the system.

CXR plays an essential role in detecting visual responses of COVID-19 infection. Chandra, Verma [16] proposed an automatic system for COVID-19 screening, named Automatic Covid

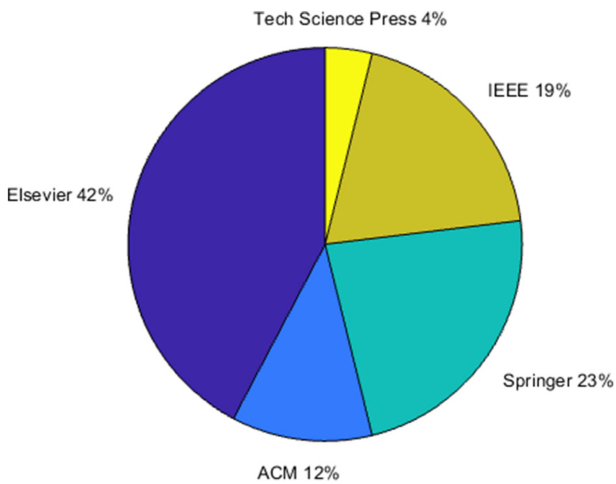

Fig. 1 Percentage of the number of articles in each electronic database

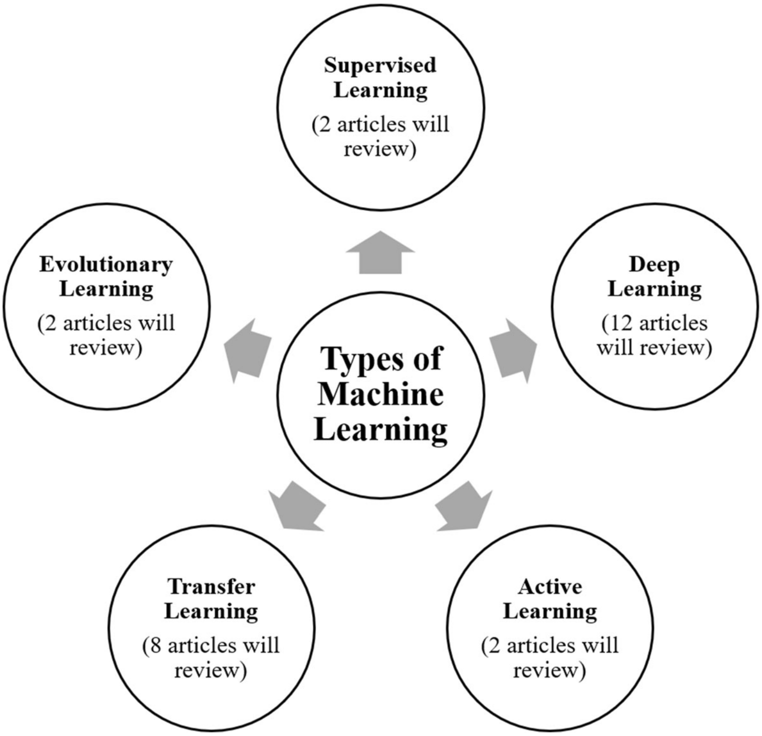

Fig. 2 ML-based COVID-19 detection from medical images techniques taxonomy

Screening (ACoS). It uses radiomic texture descriptors extracted from CXR images to classify normal, suspected, and nCOVID-19 infected individuals. Majority vote-based classifier ensemble of five supervised classification algorithms is used in the proposed ACoS. The obtained accuracy 98.062% for normal vs. abnormal classification, and 91.329% for nCOVID

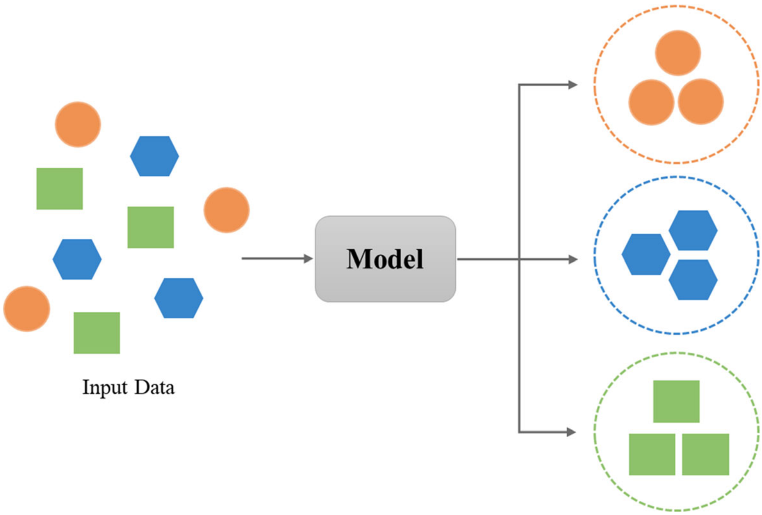

Fig. 3 Overview of supervised learning

vs. pneumonia classification reveal the promising performance of the proposed ACoS in comparison with the existing methods.

Khanday, Rabani [30] developed a method for classifying COVID-19 disease with clinical text data. Ensemble as well as traditional ML algorithms are used to classify clinical records into 4 different groups: SARS, ARDS, COVID, and both COVID + ARDS. The bag of words, and Term Frequency Inverse Document Frequency (TF-IDF) models are used for the representation of patient records. The experimental results prove that multinomial NB and logistic regression has achieve better outcomes with 96.2% accuracy rate.

It is found that most of the times ensemble classifiers produce more accurate predictions than the base classifier from which ensemble is made. Although, the reviewed methods have the drawback of higher computational time and complexity of analysis. Table 1 shows the summary of the reviewed techniques.

4.2 Deep learning-based

Deep learning is a subfield of machine learning methods. Deep learning models are based on various variants of ANNs. The algorithms can automatically learn the useful features from the raw data (Fig. 4).

Rahimzadeh and Attar [46] introduced various training methods for unbalanced datasets with fewer samples of COVID-19. In this paper, a novel hybrid neural network is introduced based on the Xception and ResNet50V2 networks. In the proposed network, the images were divided into 3 groups: normal, pneumonia, and COVID-19. Several trials are performed to apply the proposed network on a dataset with 180 X-ray images of COVID-19 patients. The proposed network is tested on 11,302 images in real circumstances. By using multiple features extracted by two robust networks, the proposed network achieved suitable accuracy. Based on the experimental results, the proposed network obtained 99.50% average accuracy for detecting COVID-19 and 91.4% for all classes.

Varela-Santos and Melin [54] developed a neural classifier for the COVID-19 diagnosis problem. In this paper, image texture feature descriptors, feed-forward, and Convolutional Neural Network (CNN) are applied to the COVID-19 diagnosis problem. A series of experiments have been performed and the results are compared with traditional supervised learning models such as the KNN and SVM. Based on the obtained results, the presented method is outperforming the traditional supervised learning models.

Also, Gupta, Gupta [21] presented a stacked deep convolution network, named InstaCovNet-19, to detect COVID-19 in CXR images. Various pre-trained models such as ResNet101, Xception, InceptionV3, MobileNet, and NASNet are used in the proposed model. The proposed InstaCovNet-19 achieved an accuracy of 99.08% for three class cases (COVID-19, pneumonia, normal) and 99.53% for binary classes (COVID, NONCOVID). The proposed model can identify COVID-19 with high accuracy.

Table 1 Summary of the covid-19 detection from medical images in supervised learning-based mechanisms

Author	Technique	Dataset	Classes	Accuracy
Chandra, Verma [16]	Majority vote-based classifier ensemble	CXR images	Binary Multi-class	98.062% 91.329%
Khanday, Rabani [30]	Majority vote-based classifier ensemble	CXR textual metadata	Multi-class	96.2%

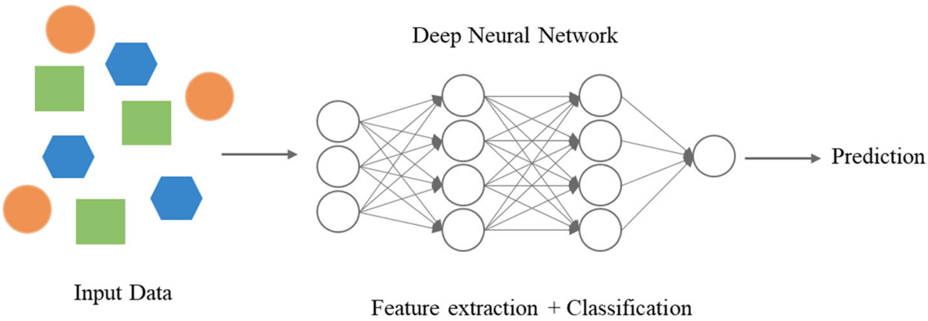

Fig. 4 Overview of deep learning [33]

Jain, Gupta [28] used a deep learning-based method on the posteroanterior view of CXR scans for the classification of COVID-19. The authors applied data augmentation and then compared different deep learning-based CNN models. The accuracy of Inception V3, Xception, and ResNeXt models have been compared. To perform the experimentations, X-ray images are collected from the Kaggle repository. Based on the results, the highest accuracy 97.97% achieved using the Xception model as compared to other models.

Padma and Kumari [43] proposed a two-dimensional (2D) CNN network for feature extraction and classification of CXR images of the lungs. A CNN network with sequential architecture and Rectified Linear Unit (ReLU) activation function are applied for implementing the classifier and features extraction. The proposed 2D convolution method has revealed significant outcomes for identifying COVID-19 at a fast rate and more than 99% accuracy.

Recently, numerous deep learning-based methods have been presented for the detection of COVID-19 using medical images. However, the proposed methods treat each CT image slice independently, which can lead to false outcomes. They are also trained and tested with images from the same dataset, which raises concerns about the generalization of methods. In order to address these problems, Silva, Luz [51] proposed a voting-based technique to present an effective deep learning method for the screening of COVID-19. The robustness of the models is validated by performing a cross dataset study. The results have confirmed that the generalization power of deep learning models is not satisfactory. Furthermore, the proposed method offers highest accuracy as compared to the state-of-the-art methods.

Al-Waisy, Al-Fahdawi [9] proposed a novel combined deep learning model for detecting COVID-19 in CXR images, called COVID-CheXNet. In the proposed system, the contrast of the X-ray image is improved and the noise level is reduced in the image pre-processing stage. The proposed COVID-CheXNet model combines the results of two pre-trained deep learning models based on a combination of ResNet34 and High-Resolution Network (HRNet) models trained using a large-scale dataset. The proposed COVID-CheXNet is developed based on a parallel architecture. COVID-CheXNet can correctly diagnose the COVID-19 patients with 99.99% accuracy.

Al-Waisy, Mohammed [10] introduced a new hybrid multimodal deep learning system for detecting COVID-19 in CXR images for rapid and accurate image analysis, called COVID-DeepNet. A hybrid Deep Belief Network (DBN) and a Convolutional Deep Belief Network (CDBN) are trained using a large-scale dataset based on a parallel architecture. The proposed COVID-DeepNet can accurately detect patients with COVID-19 with 99.93% accuracy.

Marques, Agarwal [37] introduced an automated medical diagnostic system based on the EfficientNet architecture. The EfficientNet has used a 10-fold cross-validation technique for binary and multi-class classification with a total number of 1508 x-ray images. This model reported 99.62% accuracy for binary class results. The model achieved 96.70% accuracy with multi-class classification. The proposed fine-tuned EfficientNet outperformed some of the previously released well-known CNNs like VGG, ResNet, MobileNet in terms of accuracy.

Another study by Hu, Gao [25] proposed a weakly supervised deep learning framework, in which the lung area is segmented by U-Net from the CT images. Then, a 3D deep neural network is applied on the segmented area to predict COVID-19 infection. The proposed framework could achieve an accuracy of 96.2%.

Also, a deep CNN on CXR has been presented by Ahmed, Bukhari [5] to detect COVID-19. After 5-fold cross-validation on a multi-class dataset of X-ray images, the proposed model obtained an average accuracy of 90.64%.

Finally, Harshavardhan, Bhukya [23] performed the analysis of key points from medical images of the COVID-19 dataset using Generative Adversarial Network (GAN) architecture. The patterns and key points of the medical images can be analyzed using GANs. In this paper, a higher level of accuracy and performance is obtained using the GANs as compared to the classical neural networks with multiple layers. Also, the use of GAN enhances the speed of network training.

In this section, different neural networks are presented for the diagnosis of COVID-19 using medical images. The use of deep learning for COVID-19 diagnosis based on medical imaging is a dominant method. As provided in Table 2, various researchers have developed

Table 2 Summary of the covid-19 detection from medical images in deep learning-based mechanisms

Author	Technique	Dataset	Classes	Accuracy
Rahimzadeh and Attar [46]	A hybrid neural network based on the Xception and ResNet50V2 networks	CXR images	Multi-class	91.4%
Varela-Santos and Melin [54]	Neural classifiers, including feed-forward and CNNs	CXR images	Multi-class	96.83%
Gupta, Gupta [21]	InstaCovNet-19 deep convolution network based on the ResNet101, Xception, InceptionV3, MobileNet, and NASNet models	CXR images	Multi-class Binary	99.08% 99.53%
Jain, Gupta [28]	Xception model	CXR images	Multi-class	97.97%
Padma and Kumari [43]	2D CNN network with sequential architecture and ReLU activation function	CXR images	Binary	99%
Silva, Luz [51]	A deep learning technique with a voting-based approach	CT images	Binary	87.6%
Al-Waisy, Al-Fahdawi [9]	A hybrid deep learning technique based on the ResNet34 and HRNet	CXR images	Binary	99.99%
Al-Waisy, Mohammed [10]	A hybrid deep learning technique based on a DBN and a CDBN	CXR images	Binary	99.93%
Marques, Agarwal [37]	EfficientNet	CXR images	Binary Multi-class	99.62% 96.70%
Hu, Gao [25]	Weakly supervised deep learning	CT images	Multi-class	96.2%
Ahmed, Bukhari [5]	Deep CNN	CXR images	Multi-class	90.64%

different deep learning methods. Generally, deep learning methods obtained great accuracy in determining COVID-19 using radiology images. However, high computational time still remain as a problem in these methods.

4.3 Active learning-based

Active learning is a machine learning algorithm that chooses a subgroup of the data which it needs to learn. As shown in Fig. 5, sample data are selected from a pool of unlabeled data and then labeled. This algorithm performs better than traditional methods with considerably less labeled data for training. These algorithms are useful in cases where unlabeled data may be abundant but labels are difficult to obtain.

Wu, Chen [56] proposed COVID-AL, a weakly-supervised deep active learning framework, to identify COVID-19 with CT images. In the proposed framework, patient-level labels are used for data labeling. A 2D U-Net architecture is used for lung region segmentation. Also, a new hybrid active learning strategy is implemented to detect COVID-19. The proposed framework can efficiently identify COVID-19 using a custom 3D residual network. Several experiments are performed on a CT scan dataset from the Consortium of Chest CT Image Investigation (CC-CCII). The obtained outcomes validate that the proposed framework outperforms the common active learning methods. Using 30% of the labeled data, COVID-AL achieved more than 95% accuracy. The effectiveness and efficiency of COVID-AL proved based on qualitative and quantitative analysis.

Also, Santosh [47] emphasized the need for active learning techniques incorporating novel data types to distinguish new outbreaks of the COVID-19 infection. The authors concluded that active-learning based cross-population train/test models with multitudinal and multimodal data are useful tools for AI-based COVID-19 diagnosis. However, complexity of such methods grows exponentially with the dimension.

The active learning-based mechanisms are summarized in Table 3. These methods are very efficient, but they require longer supervision of human experts.

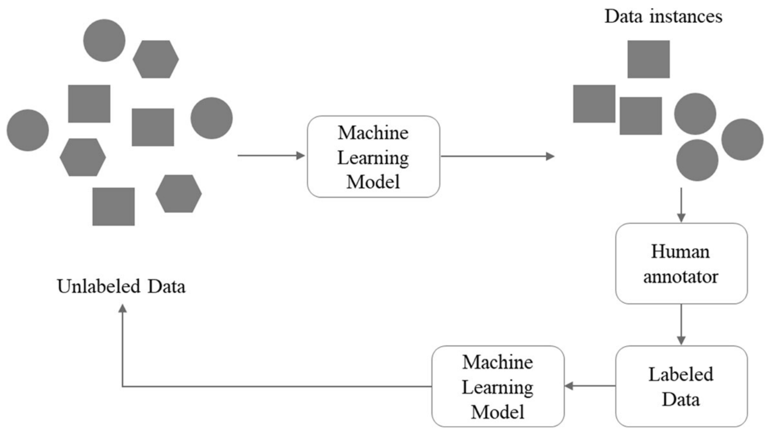

Fig. 5 Overview of active learning [48]

Table 3 Summary of the covid-19 detection from medical images in active learning-based mechanisms

Author	Technique	Dataset	Classes	Accuracy
Wu, Chen [56]	A hybrid deep active learning framework	CT images	Multi-class	95%

4.4 Transfer learning-based

The main goal of transfer learning is to transfer knowledge from one supervised learning task to another. It needs further labeled data from a different but related task (Fig. 6). The need for additional labeled data for the new supervised learning tasks is the main limitation of this method.

Brunese, Mercaldo [15] applied deep learning on X-rays for faster diagnosis of COVID-19. The proposed technique includes three phases. First, the presence of a pneumonia in a CXR is detected. Next, the proposed system distinguishes among COVID-19 and pneumonia. In the last stage, the proposed model maps the probable localization of COVID-19 on the X-ray image. The presented model obtained good outcomes, with an accuracy of 97% and approximately 2.5 s.

Panwar, Gupta [45] proposed nCOVnet, a deep learning neural network-based technique, for the detection of COVID-19 based on X-ray images. The proposed nCOVnet model with transfer learning is trained on the COVID-19 dataset. The proposed nCOVnet method achieved 97.60% accuracy for binary classification. Furthermore, recognition of COVID-19 patients is performed more rapidly by identifying the features of infected patients as hazy or shadowy patches.

Apostolopoulos and Mpesiana [11] used different combinations of transfer learning with CNN networks for large scale image classification. The authors analyzed 224 COVID-19 medical images, 700 pneumonias, and 504 normal images. The proposed method has obtained 96.78% accuracy for differentiation of COVID-19 and healthy individuals.

Pandit, Banday [44] used transfer learning with fine-tuning to learn from small dataset of chest radiographs. The pre-trained VGG-16 model is used for the classification problem. The used dataset includes chest radiographs with COVID-19, pneumonia, and normal cases. Based on the experiments, an accuracy of 96% and 92.5% is achieved in two and three output class cases.

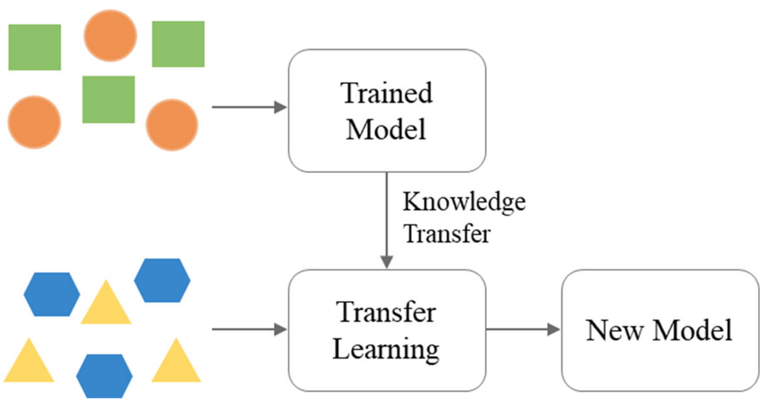

Fig. 6 Overview of transfer learning [55]

Abbas, Abdelsamea [1] proposed a deep CNN, called Decompose, Transfer, and Compose (DeTraC). In the proposed model, a modified version of the ResNet-18 pre-trained model is used to classify the COVID-19 CXR data into three classes. Also, decomposition procedure is used for investigating the irregularities in class boundaries. The proposed DeTraC obtained an accuracy of 95%.

Horry, Chakraborty [24] investigated the performance of seven CNN models for classifying COVID-19 in three different datasets called: VGG-16, DenseNet121, VGG-19, Xception, ResNet50v2, Inceptionv3 and NASNetLarge. Based on the results, it becomes evident that the VGG16 network outperforms the other networks based on the F1 score. These models are applied to CT, Ultrasound, and X-ray multimodal data. The experimental outcomes revealed that Ultrasound images achieved more precision compared to X-ray and CT scans. Furthermore, the presented VGG-19 model is enhanced for the image modalities. The enhanced VGG-19 tuned with appropriate parameters. The accuracy of more than 86% for X-ray, 100% for Ultrasound and 84% for CT scans is obtained by the enhanced VGG-19.

Chen, Jaegerman [17] proposed a transfer learning model to identify COVID-19 from X-ray images. The presented model is built on top of the VGG-16 neural network and the weights trained on ImageNet data. Gradient-weighted Class Activation Mapping (Grad-CAM) is also implemented to identify the regions with more impact on the proposed learning model decision. The proposed VGG-16 network obtained a good accuracy of 98% as compared to Inception-V3, Inception-ResNet, Xception, RestNet152-V2, and DenseNet201 models.

Makris, Kontopoulos [36] compared several pre-trained CNN networks to identify COVID-19 infected patients from CXR dataset of COVID-19, pneumonia, and normal individual. The trial outcomes proved that the best accuracy of 95% achieved for the VGG-16 and VGG-19 models.

The COVID-19 detection based on transfer learning techniques has high accuracy, and low time. These methods enable learning from associated domains, to make the models work well in new domains. Thereby, transfer learning techniques have low computational cost and high scalability in comparison with deep learning models. The reviewed transfer learning-based mechanisms are summarized in Table 4.

4.5 Evolutionary learning-based

In evolutionary algorithms, the most optimal solution for a particular problem is discovered from a set of alternative solutions. The COVID-19 detection problem can be represented as an image processing problem, which includes image segmentation and feature extraction. These issues can be solved by evolutionary algorithms with less computational effort in an acceptable time.

El-Kenawy, Ibrahim [20] presented a new framework for features selection and voting classifier for the detection of COVID-19 from CT images. Firstly, a CNN network named AlexNet used for feature extraction. Then, the new feature selection algorithm, Stochastic Fractal Search (SFS)-Guided Whale Optimization Algorithm (WOA), is employed to select the useful features. In the last phase, a new voting classifier, Guided WOA based on Particle Swarm Optimization (PSO), is adopted to select the most voted class in an ensemble learning manner. To validate the effectiveness of the introduced SFS-Guided WOA method, it is compared with various state-of-the-art optimization algorithms. Also, the proposed PSO-Guided-WOA classifier obtained an accuracy of 99.5%, which is better than other voting classifiers. Furthermore, the authors have confirmed the performance of the proposed algorithms by applying various statistical tests.

Table 4 Summary of the covid-19 detection from medical images in transfer learning-based mechanisms

Author	Technique	Dataset	Classes	Accuracy
Brunese, Mercaldo [15]	Transfer learning using VGG-16 pre-trained model	CXR images	Multi-class	97%
Panwar, Gupta [45]	Deep learning neural network-based method based on a transfer learning model	CXR images	Binary	97.60%
Apostolopoulos and Mpesiana [11]	Transfer learning with convolutional neural networks	CXR images	Multi-class	96.78%
Pandit, Banday [44]	Transfer learning using VGG-16 pre-trained model	CXR images	Binary Multi-class	96% 92.5%
Abbas, Abdelsamea [1]	A deep CNN with ResNet-18 architecture	CXR images	Multi-class	95%
Horry, Chakraborty [24]	Transfer learning using VGG-19 pre-trained model	CXR images CT images Ultrasound	Multi-class Binary Multi-class	86% 84% 100%
Chen, Jaegerman [17]	Transfer learning with VGG-16 model	CXR images	Multi-class	98%
Makris, Kontopoulos [36]	Pre-trained CNNs with transfer learning (VGG-16 and VGG-19 models)	CXR images	Multi-class	95%

Abdel-Basset, Mohamed [2] proposed a combined COVID-19 diagnosis model based on Marine Predators Algorithm (IMPA) and Ranking-based Diversity Reduction (RDR) strategy. The authors performed several experiments for the validation of IMPA performance on the CXR images. The results of the proposed hybrid model compared with several optimization algorithms. The obtained results indicated that the enhanced version of the IMPA algorithm outperforms all other state-of-the-art algorithms for a range of metrics.

Table 5 reveals the summary of the reviewed techniques.

5 Results and comparisons

The selected ML-based COVID-19 detection mechanisms are reviewed in the previous section. The most important ML-based COVID-19 detection mechanisms until 2021 are described. As stated in the previous sections, supervised learning-based, deep learning-based, active learning-based, transfer learning-based, and evolutionary learning-based mechanisms are five main categories of ML-based COVID-19 detection mechanisms. Figure 7 shows the popularity of various ML techniques in the diagnosis of COVID-19 using medical imaging, which clearly shows that deep learning, and transfer learning are the most popular ones. As shown in Fig. 8, the popular network that researchers used to detect COVID-19 is VGG with 33%.

The results reveal that accuracy and time of the proposed techniques are in the center of attention. Based on the results of the studied papers, it can be seen that the best accuracy of 99.08% is obtained by using the InstaCovNet-19 deep convolution network for CXR images.

Table 5 Summary of the covid-19 detection from medical images in evolutionary learning-based mechanisms

Author	Technique	Dataset	Classes	Accuracy
El-Kenawy, Ibrahim [20]	Voting classifier framework for COVID-19 CT image classification	CT images	Binary	99.5%

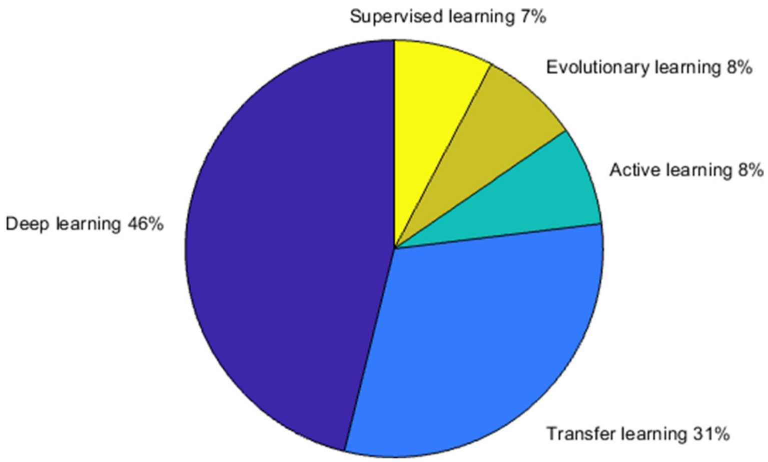

Fig. 7 Various types of ML techniques used in the selected articles

Furthermore, Xception and the proposed transfer learning with VGG-16 model by [17] had the highest accuracies of 97.97% and 98%.

As shown in Fig. 9, the most popular dataset that researchers used to detect COVID-19 is X-ray images with 77%. The mean detection of all studies using X-ray method had an average accuracy of 96.09%. Also, it can be concluded that in detecting COVID-19 using CT scan images, ML models achieved an average accuracy of 92.46%.

6 Open issues

Recently, the applications of AI methods for the diagnosis of COVID-19 have increased. The data gathered in this paper explain the state-of-the-art in the field of automatic COVID-19 detection mechanisms and approaches from medical images. However, these techniques have some limitations and challenges such as insufficient training and validation data, and poor-

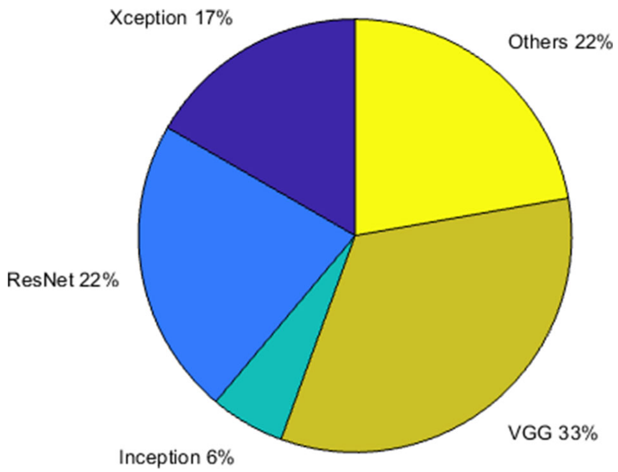

Fig. 8 Deep neural network models used for COVID-19 detection in the selected articles

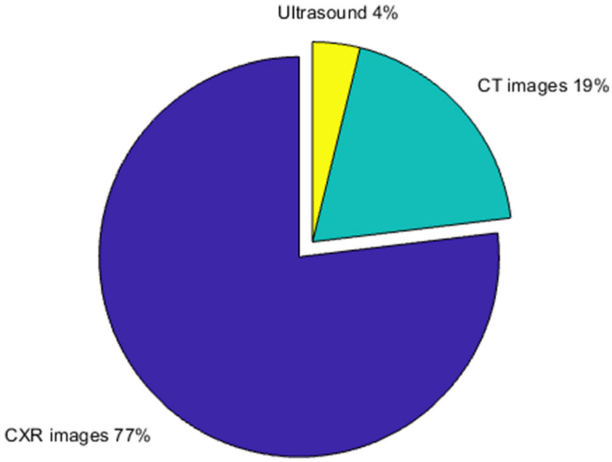

Fig. 9 Rate of using different imaging techniques in processing of COVID-19

quality data. This part offers some challenges for COVID-19 detection using ML techniques from various perspectives.

Processing huge quantities of data Processing of large amounts of unstructured, incomplete, inconsistent, and imprecise medical data is a critical issue in the process of medical analysis. Various AI techniques must be implemented to analyze such large amounts of such data in real-time. Therefore, the scalability and efficiency of existing analytics algorithms used for medical imaging must be investigated and improved.

Access to COVID-19 datasets AI methods need huge quantities of data to acquire knowledge. Due to the limited access to related data in the field of COVID-19, there are still limited AI applications for COVID-19 diagnosis using medical imaging. However, ML is one of the most common techniques in the diagnosis of COVID-19, developers should improve generalization and prevent overfitting of ML-based models for COVID-19 diagnosis. It is essential to train these models on large and heterogeneous datasets to cover the entire data space. Future work on creating COVID-19 related datasets is essential as it helps to speed up useful discoveries to fight the disease [40].

Qualitative parameters and metrics As reviewed in this survey, various AI methods applied to detect COVID-19 diagnosis using medical imaging. The authors used different qualitative attributes to validate the proposed techniques. However, the study of COVID-19 detection using ML techniques on the same real-world datasets, with the same methods and the same trial infrastructure and their evaluation using various quality attributes is very interesting.

7 Conclusion

The COVID-19 infection has a significant impact on human life around the world [14]. Various types of tests are used to detect the presence of COVID-19. Several studies have used medical images to detect anomalies indicating COVID-19. ML has a key role in various applications such as medical image processing and disease detection. With the increasing development of ML techniques, the need for evaluation and benchmarking ML techniques to select the appropriate method for the classification of COVID-19 medical images increases. Therefore, a systematic review of ML mechanisms in the detection and classification of COVID-19 medical images in terms of evaluation and benchmarking is presented in this paper. According to the performed review, we introduced a taxonomy for AI-driven COVID-19 detection mechanisms and approaches from medical images based on learning techniques. The selected 26 articles are reviewed in five main categories including supervised learning-based, deep learning-based, active learning-based, transfer learning-based, and evolutionary learning-based mechanisms. From our survey, the use of deep learning and transfer learning methods for the detection of COVID-19 based on medical images is dominant. It is obvious that most of the researchers used CXR to diagnose COVID-19 because CT scans are more expensive and time-consuming with less accuracy. There is also a shortage of annotated medical images of COVID-19 affected people. We remarked that the use of segmentation as preprocessing has a significant effect on the performance of the model. Furthermore, this review introduces some interesting lines for future research.

This survey tries to conduct a comprehensive and systematic review but also has some limitations. It fails to review ML-driven COVID-19 diagnosis techniques that are available in different sources. Furthermore, this work can be considered as a preliminary study since many different ML techniques are being presented to control the COVID-19 pandemic at the present time. Despite this, the results will help researchers to develop more effective ML-driven methods for the detection of COVID-19 from medical images.

Code availability Not applicable.

Funding The author(s) received no specific funding for this work.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Abbas A, Abdelsamea MM, Gaber MM (2021) Classification of COVID-19 in chest X-ray images using DeTraC deep convolutional neural network. Appl Intell 51(2):854–864
2. Abdel-Basset M, Mohamed R, Elhoseny M, Chakrabortty RK, Ryan M (2020) A hybrid COVID-19 detection model using an improved marine predators algorithm and a ranking-based diversity reduction strategy. IEEE Access 8:79521–79540
3. Abdulkareem KH et al (2021) Realizing an effective COVID-19 diagnosis system based on machine learning and IOT in smart hospital environment. IEEE Internet of Things J 8(21):15919–15928
4. Adly AS, Adly AS, Adly MS (2020) Approaches based on artificial intelligence and the internet of intelligent things to prevent the spread of COVID-19: scoping review. J Med Internet Res 22(8):e19104
5. Ahmed F, Bukhari SAC, Keshtkar F (2021) A deep learning approach for COVID-19 8 viral pneumonia screening with X-ray images. Digital Gov: Res Pract 2(2):1–12
6. Albahli S et al (2021) COVID-19 public sentiment insights: a text mining approach to the Gulf countries. Comp Mater Continua 67(2):1613–1627

7. Albahri O et al (2020) Systematic review of artificial intelligence techniques in the detection and classification of COVID-19 medical images in terms of evaluation and benchmarking: taxonomy analysis, challenges, future solutions and methodological aspects. J Infect Public Health 13(10):1381–1396
8. Alsharif W, Qurashi A (2020) Effectiveness of COVID-19 diagnosis and management tools: a review. Radiography 27:682–687
9. Al-Waisy AS et al (2020) COVID-CheXNet: hybrid deep learning framework for identifying COVID-19 virus in chest X-rays images. Soft Comput 2020:1–16
10. Al-Waisy A et al (2021) COVID-DeepNet: hybrid multimodal deep learning system for improving COVID-19 pneumonia detection in chest X-ray images. *Comp Mater Continua* 67(2):2409–2429
11. Apostolopoulos ID, Mpesiana TA (2020) Covid-19: automatic detection from x-ray images utilizing transfer learning with convolutional neural networks. Phys Eng Sci Med 43:635–640
12. Arabi H, Zaidi H (2020) Applications of artificial intelligence and deep learning in molecular imaging and radiotherapy. Eur J Hybrid Imaging 4(1):1–23
13. Bhattacharya S, Reddy Maddikunta PK, Pham QV, Gadekallu TR, Krishnan S SR, Chowdhary CL, Alazab M, Jalil Piran M (2021) Deep learning and medical image processing for coronavirus (COVID-19) pandemic: a survey. Sustain Cities Soc 65:102589
14. Blbas HT, Faraj SM (2022) A statistical study of the influence of COVID-19 on the agricultural supply chain (vegetative) production in Halabja governorate. Cihan University-Erbil Scientific Journal 6(1):1–6
15. Brunese L, Mercaldo F, Reginelli A, Santone A (2020) Explainable deep learning for pulmonary disease and coronavirus COVID-19 detection from X-rays. Comput Methods Prog Biomed 196:105608
16. Chandra TB et al (2020) Coronavirus disease (COVID-19) detection in chest X-ray images using majority voting based classifier ensemble. Expert Syst Appl 165:113909
17. Chen A et al (2020) Detecting Covid-19 in chest X-rays using transfer learning with VGG16. In: CSBio'20: proceedings of the eleventh international conference on computational systems-biology and bioinformatics, pp 93–96
18. Chen J et al (2021) A survey on applications of artificial intelligence in fighting against covid-19. ACM Computing Surveys (CSUR) 54(8):1–32
19. Dong D et al (2020) The role of imaging in the detection and management of COVID-19: a review. IEEE Rev Biomed Eng 14:16–29
20. El-Kenawy E-SM et al (2020) Novel feature selection and voting classifier algorithms for COVID-19 classification in CT images. IEEE Access 8:179317–179335
21. Gupta A, Gupta S, Katarya R (2020) InstaCovNet-19: A deep learning classification model for the detection of COVID-19 patients using Chest X-ray. Appl Soft Comput 99:106859
22. Harapan H et al (2020) Coronavirus disease 2019 (COVID-19): a literature review. J Infect Public Health 13(5):667–673
23. Harshavardhan A, Bhukya H, Prasad AK (2020) Advanced machine learning-based analytics on COVID-19 data using generative adversarial networks. Proc, Mater Today
24. Horry MJ, Chakraborty S, Paul M, Ulhaq A, Pradhan B, Saha M, Shukla N (2020) COVID-19 detection through transfer learning using multimodal imaging data. IEEE Access 8:149808–149824
25. Hu S, Gao Y, Niu Z, Jiang Y, Li L, Xiao X, Wang M, Fang EF, Menpes-Smith W, Xia J, Ye H, Yang G (2020) Weakly supervised deep learning for covid-19 infection detection and classification from ct images. IEEE Access 8:118869–118883
26. Huang X, Shirahama K, Li F, Grzegorzek M (2020) Sleep Stage Classification for Child Patients Using DeConvolutional Neural Network. Artif Intell Med 110:101981
27. Huh J-H, Seo Y-S (2019) Understanding edge computing: engineering evolution with artificial intelligence. IEEE Access 7:164229–164245
28. Jain R, Gupta M, Taneja S, Hemanth DJ (2020) Deep learning based detection and analysis of COVID-19 on chest X-ray images. Appl Intell 51:1–11
29. Kannan S, Subbaram K, Ali S, Kannan H (2020) The role of artificial intelligence and machine learning techniques: Race for covid-19 vaccine. Arch Clin Infect Dis 15(2):e103232
30. Khanday AMUD, Rabani ST, Khan QR, Rouf N, Mohi Ud Din M (2020) Machine learning based approaches for detecting COVID-19 using clinical text data. Int J Inf Technol 12(3):731–739
31. Kitchenham B (2004) Procedures for performing systematic reviews. Keele, UK. Keele Univ 33(2004):1–26
32. Lalmuanawma S, Hussain J, Chhakchhuak L (2020) Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV-2) pandemic: a review. Chaos, Solitons Fractals 139:110059
33. LeCun Y, Bengio Y, Hinton G (2015) Deep learning. Nature 521(7553):436–444
34. Liang T (2020) Handbook of COVID-19 prevention and treatment. In: The first affiliated hospital, Zhejiang University School of Medicine. Compiled according to clinical experience, p 68

35. Mahfouz MA, Shoukry A, Ismail MA (2020) EKNN: Ensemble Classifier Incorporating Connectivity and Density into kNN with Application to Cancer Diagnosis. Artif Intell Med 111:101985
36. Makris A, Kontopoulos I, Tserpes K (2020) COVID-19 detection from chest X-ray images using deep learning and convolutional neural networks. In 11th Hellenic conference on. Artif Intell:60–66
37. Marques G, Agarwal D, de la Torre Díez I (2020) Automated medical diagnosis of COVID-19 through EfficientNet convolutional neural network. Appl Soft Comput 96:106691
38. Mohammed MA, Abdulkareem KH, al-Waisy AS, Mostafa SA, al-Fahdawi S, Dinar AM, Alhakami W, Baz A, al-Mhiqani MN, Alhakami H, Arbaiy N, Maashi MS, Mutlag AA, Garcia-Zapirain B, de la Torre Diez I (2020) Benchmarking methodology for selection of optimal COVID-19 diagnostic model based on entropy and TOPSIS methods. IEEE Access 8:99115–99131
39. Mohammed MA et al (2020) A comprehensive investigation of machine learning feature extraction and classification methods for automated diagnosis of covid-19 based on x-ray images. Comp Mater Continua 66(3):3289–3310
40. Nguyen TT (2020) Artificial intelligence in the battle against coronavirus (COVID-19): a survey and future research directions. Preprint 10
41. Organization, W.H (2020) Clinical management of severe acute respiratory infection when novel coronavirus (2019-nCoV) infection is suspected: interim guidance, in clinical management of severe acute respiratory infection when novel coronavirus (2019-nCoV) infection is suspected: interim guidance, pp 21–21
42. Ozsahin I, Sekeroglu B, Musa MS, Mustapha MT, Uzun Ozsahin D (2020) Review on diagnosis of COVID-19 from chest CT images using artificial intelligence. Comp Math Methods Med 2020:1–10
43. Padma T, Kumari CU (2020) Deep learning based chest X-ray image as a diagnostic tool for COVID-19. In: 2020 international conference on smart electronics and communication (ICOSEC). IEEE
44. Pandit MK, Banday SA, Naaz R, Chishti MA (2020) Automatic detection of COVID-19 from chest radiographs using deep learning. Radiography 27:483–489
45. Panwar H et al (2020) Application of deep learning for fast detection of COVID-19 in X-rays using nCOVnet. Chaos, Solitons Fractals 138:109944
46. Rahimzadeh M, Attar A (2020) A modified deep convolutional neural network for detecting COVID-19 and pneumonia from chest X-ray images based on the concatenation of Xception and ResNet50V2. Informatics in Medicine Unlocked 19:100360
47. Santosh K (2020) AI-driven tools for coronavirus outbreak: need of active learning and cross-population train/test models on multitudinal/multimodal data. J Med Syst 44(5):1–5
48. Settles B (2009) *Active learning literature survey*. University of Wisconsin-Madison Department of Computer Sciences, Madison
49. Shi F et al (2020) Review of artificial intelligence techniques in imaging data acquisition, segmentation and diagnosis for covid-19. IEEE Rev Biomed Eng 14:4–15
50. Shuja J et al (2021) Covid-19 open source data sets: a comprehensive survey. Appl Intell 51(3):1296–1325
51. Silva P, Luz E, Silva G, Moreira G, Silva R, Lucio D, Menotti D (2020) COVID-19 detection in CT images with deep learning: a voting-based scheme and cross-datasets analysis. Inform Med Unlocked 20:100427
52. Srivastava S, Pant M, Agarwal R (2020) Role of AI techniques and deep learning in analyzing the critical health conditions. Int J Syst Assurance Eng Manag 11(2):350–365
53. Vaishya R et al (2020) Artificial intelligence (AI) applications for COVID-19 pandemic. Diab Metab Syndr: Clin Res Rev 14(4):337–339
54. Varela-Santos S, Melin P (2020) A new approach for classifying coronavirus COVID-19 based on its manifestation on chest X-rays using texture features and neural networks. Inf Sci 545:403–414
55. Weiss K, Khoshgoftaar TM, Wang D (2016) A survey of transfer learning. J Big Data 3(1):9
56. Wu X et al (2020) COVID-AL: the diagnosis of COVID-19 with deep active learning. Med Image Anal 68:101913

Affiliations

Amir Masoud Rahmani[1] • **Elham Azhir**[2] • **Morteza Naserbakht**[3] • **Mokhtar Mohammadi**[4] • **Adil Hussein Mohammed Aldalwie**[5] • **Mohammed Kamal Majeed**[6] • **Sarkhel H. Taher Karim**[7,8] • **Mehdi Hosseinzadeh**[9]

✉ Mehdi Hosseinzadeh
hosseinzadeh.m@iums.ac.ir

1 Future Technology Research Center, National Yunlin University of Science and Technology, Douliu, Yunlin, Taiwan

2 Research and Development Center, Mobile Telecommunication Company of Iran, Tehran, Iran

3 Mental Health Research Center, Psychosocial Health Research Institute, Iran University of Medical Sciences, Tehran, Iran

4 Department of Information Technology, College of Engineering and Computer Science, Erbil, Kurdistan Region, Iraq

5 Department of Communication and Computer Engineering, Faculty of Engineering, Cihan University-Erbil, Kurdistan region, Iraq

6 Information Technology Department, Faculty of Applied Science, Tishk International University, Erbil, Iraq

7 Computer Department, College of science, University of Halabja, Halabja, Iraq

8 Computer Networks Department, Sulaimani Polytechnic University, Technical College of Informatics, Sulaymaniyah, Iraq

9 Computer Science, University of Human Development, Sulaymaniyah, Iraq