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REVIEW

Computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches

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Abstract
The infectious disease Covid-19 has been causing severe social, economic, and human suffering across the globe since 2019. The countries have utilized different strategies in the last few years to combat Covid-19 based on their capabilities, technological infrastructure, and investments. A massive epidemic like this cannot be controlled without an intelligent and automatic health care system. The first reaction to the disease outbreak was lockdown, and researchers focused more on developing methods to diagnose the disease and recognize its behavior. However, as the new lifestyle becomes more normalized, research has shifted to utilizing computer-aided methods to monitor, track, detect, and treat individuals and provide services to citizens. Thus, the Internet of things, based on fog-cloud computing, using artificial intelligence approaches such as machine learning, and deep learning are practical concepts. This article aims to survey computer-based approaches to combat Covid-19 based on prevention, detection, and service provision. Technically and statistically, this article analyzes current methods, categorizes them, presents a technical taxonomy, and explores future and open issues.

Keywords Internet of things · Machine learning · Fog computing · Cloud computing

1 Introduction

Covid-19 is viewed as the most critical and new virus of our time, as it has the potential to spread viral diseases worldwide [1]. In December 2019, a new infectious disease was found in Wuhan, China, caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and characterized by mild or moderate respiratory symptoms. The World Health Organization (WHO) declared the disorder a pandemic on March 11, 2020, and no definitive solution to its eradication has yet been found. During the epidemic's early stages, government actions included lockdowns, business closures, and workplace hazard control. All these measures resulted in severe economic and social challenges. Over about two years after the outbreak, governments have adopted more intelligent strategies to restore normal living conditions. As governments could not keep their country locked down forever, a whole new lifestyle developed along with Covid-19. People use computer-based technologies to be aware of their health status and receive alerts for the presence of infected and suspicious people around them—for example, Radio Frequency Identification (RFID) tags, mobile applications, and smart gadgets. Through IoT technology, the healthcare system collects data, transfers it to centralized servers, analyzes the data, and diagnoses people's health status nationally, from personal to government-level dimensions. On an urban scale, the unmanned aerial vehicle (UAV) with thermal cameras monitors large geographical areas to identify high-risk zones to develop appropriate control policies [2]. Also, automated drones and intelligent robots deliver drugs and vaccines to inaccessible regions and perform sampling of infected people without the intervention of medical staff, which effectively reduces the possibility of spreading the virus [3]. A medical center, because of its large number of patients, its limited

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availability of medical staff and equipment, and the lengthy diagnosis process, cannot control the situation without leveraging AI methods, such as DL, classification, and feature selection, along with IoT devices, big data, and cloud-based networks [4, 5].

Deep learning and machine learning (ML) methods can learn from several patient datasets, use object detection techniques, and then verify diseases which is much faster and more accurate than human diagnostic methods. Combining AI with the IoT has created a new medical system that, despite its advantages over traditional medicine, has challenges such as maintaining the security, integrity, and confidentiality of data mentioned by Aman et al. [6]. Cameras, sensors, and intelligent tags everywhere, including homes, workplaces, streets, and busy places such as stores and hospitals, perform a kind of screening operation through monitoring [5, 7–9]. Depending on their settings, these devices will alert if a suspected infection is detected. Wearable devices connected to monitoring and tracking applications can also surveil environments and inform their health status [10]. Most businesses turned to telework during the epidemic, relying on computer networks and equipment. Humans are social creatures who require communication and interaction with others. People meet this need through social media and communication apps during the long-term quarantine of an epidemic. Instagram, Facebook, YouTube, and other social platforms are tools for entertainment and communication with friends and relatives. Also, making video calls even in group forms on the Internet has partially replaced the meetings in cafes and restaurants. Virtual education has also replaced physical communities in colleges and schools on various platforms. Computer science-based technologies at all levels of individual and social life help change daily activities, work, education, and treatment to telecommunications. Although many of these technologies existed before the Covid-19 disease, their vital role may have become more apparent after the epidemic [11–13]. According to what has been said previously, a world without computer science and its technologies is unimaginable. This article will describe the role of computer science and related technologies in the three areas of prevention, diagnosis, and service delivery in detail, based on numerous studies conducted since 2020 [14, 15].

In the fight against the spread of the Covid-19 disease, many countries have actively employed computer-based technologies, such as AI, big data, the IoT, cloud computing, and blockchain, which have improved monitoring, detection, prevention, treatment, and service provision for Covid-19. As depicted in Fig. 1, this article investigates three distinct aspects of threat prevention, Covid-19 detection, and service provision during the outbreak of this disease utilizing learning-based algorithms and computer-aided technologies.

Using AI algorithms and a comprehensive model for the spread of Covid-19, it is possible to predict changes in the spread of the virus several days in advance. This period is ideal for drafting regulations and preventing the rapid spread of Covid-19. The model can make predictions by collecting Covid-19-related data from social networks such as Facebook, Twitter, and the Google search engine. Therefore, to prevent the spread of this virus, it is possible to implement effective public health measures, such as quarantine and appropriate restrictions. Also, researchers can identify the source of the spread of different Covid-19 variants using computer programs. They can determine which human population or age group is most at risk. Therefore, with proper prediction, appropriate regulations can be enforced to prevent the spread of Covid-19 among the same target population.

In crowded places and public places such as metro stations, where traditional methods of measuring human body temperature are time-consuming and can cause healthy people to become infected with Covid-19 due to crowding, AI algorithms using digital cameras and infrared technology can be used to measure temperature. This technology made it possible to measure human body temperature accurately and reliably without physical contact, allowing for the rapid identification of individuals whose body temperature exceeded the predetermined threshold.

Sometimes, the number of Covid-19 patients exceeds the capacity of the country's hospitals, resources, and medical equipment due to the epidemic. In many cases, patients suffering from severe respiratory syndrome require urgent services such as an ambulance, nurse, medication, and oxygen generator; failure to provide these services on time can result in patient death. Consequently, these services are provided at the patient's location using cloud-based computer programs and the use of smartphones by patients to request such services. In addition, the spread of the Covid-19 virus is increasing the demand for online meetings, video conferences, and online teaching. Such services can be supplied by cloud computing-based service providers.

In many technical surveys and review articles, computer-based methods are not systematically discussed to prevent and detect Covid-19. This study examines the role of computer technologies in combating Covid-19 by preventing its spread, improving the accuracy of diagnosis, and delivering single and composing services to people in the community during an epidemic. The fundamental methods based on computer science in selected studies include prevention, detection, and service composition for all users. A Systematic Literature Review (SLR) presents an overview of the limitations and opportunities of using

Fig. 1 Computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches

computer-aided methods for detecting, and preventing Covid-19 is presented using an SLR. These are the primary objectives of this study:

- The technical taxonomy classifies the various computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches.
- Discussing and comparison of the main challenges encountered in combating Covid-19 using computer-aided methods
- Focusing on the research challenges and open issues associated with computer-aided methods for combatting Covid-19

Table 1 summarized the definitions of the most used terms in our study.

Table 2 contains a list of essential abbreviations included to facilitate comprehension of the paper.

Considering that each paper uses different metrics to evaluate its ideas, we listed and defined all the evaluation metrics used in our study in Table 3.

Following is a description of how this study has been organized: Sect. 2 discusses the related work. Section 3 provides a methodology for selecting research according to the SLR method. A systematic overview is provided in Sect. 4 to describe how computer-aided methods are used to combat Covid-19 and provide related services. In addition, a comparison of selected papers is presented, and a technical taxonomy is described. A discussion of the topic is presented in Sect. 5. Finally, Sect. 6 presents a conclusion and the limitations of the study.

Table 1 Definitions of repetitive phrases

Phrase	Definition of phrase
Internet of things (IoT)	It refers to a network of physical devices that collects and shares information
Internet of medical things (IoMT)	An information technology network in healthcare includes interconnected medical devices, infrastructure, and applications
Cloud computing	Different services such as data storage and processing by powerful servers, software, and infrastructures are provided over the Internet in cloud computing
Artificial intelligence (AI)	A branch of computer science in which computers and machines simulate human thought and decision-making
Machine learning (ML)	ML refers to studying computer algorithms that can learn through experience and data analysis
Deep learning (DL)	DL is a part of a larger group of ML techniques that imitates the human brain's learning process by clustering data and making accurate predictions
Big data	It consists of too large or complex data collection for traditional data-processing software
Wearable technology	It refers to electronic devices worn by consumers to collect personal health information and measure exercise
Unmanned aerial vehicle (UAV)	UAV, commonly known as a drone, is a remote-controlled flying computer equipped with cameras and sensors

Table 2 List of abbreviations

Abbreviation form	Complete form
CNN	Convolutional neural network
DSVM	Deep support vector machine
FL	Federated learning
LSTM	Long short-term memory
MAPE	Mean absolute percentage error
MCC	Matthews correlation coefficient
MDP	Markov decision process
MTGP	Multi-task Gaussian process
MEC	Mobile edge computing
NLP	Natural language processing
NN	Neural network
PSO	Particle swarm optimization
K-Nearest Neighbors	KNN
RF	Random forest
RFID	Radio frequency identification
RMSE	Root mean square error
RNN	Recurrent neural network
ROC	Receiver operating characteristic
SLR	Systematic literature review
SVM	Support vector machine
TRNN	Temporal recurrent neural network
GA	Genetic algorithm

2 Related work

Convolutional neural networks (CNN) are a type of NN that is most frequently used to analyze visual imagery. CNNs are frequently referred to as regularized versions of multilayer perceptrons. It indicates that every neuron in one layer is connected to every neuron in the following layer. CNNs are susceptible to overfitting due to their full interconnection. Regularization, or the prevention of overfitting, typically involves penalizing parameters during training or reducing connection. CNNs take a different method to regularization: they take advantage of the hierarchical structure in the data and create highly complicated patterns from smaller, simpler patterns imprinted in their filters. Therefore, CNNs are at the bottom of the interconnection and complexity scale [16].

ResNet50 is one of the most often used CNN architectures for more robust training. ResNet-50 contains 50 layers, and the idea behind ResNet50 design is to employ the identity shortcut connection, which allows the layers to be skipped and allows for a rapid learning process. This design allows the first network layers to communicate directly. Consequently, it will be easy for the first layers to update their gradients [27].

A Capsule Neural Network (CapsNet) is a NN that can be used to model hierarchical relationships more accurately. The method is an attempt to emulate real brain architecture more precisely. The CapsNet aims to add structures known as capsules to a CNN and to reuse output from several of those capsules to construct representations for higher capsules that are more robust [17].

For the development of the CovTinyNet model, a type of CNN, the architecture of the real-time object detection system You Only Look Once (YOLOv3 tiny) serves as the foundation. To improve the speed and accuracy of real-time diagnosis, the number of layers employed in the CovTinyNet model has been reduced. Additionally, CovTinyNet implemented extra skip connections to preserve local data. This enhances the model's ability to accurately detect and localize abnormalities in medical images. The model is also easy to deploy on any small device due to the reduction in its file size [35].

Gradient-weighted Class Activation Mapping (Grad-CAM) represents a rigorous generalization of the Class Activation Mapping, which is a straightforward method for obtaining the discriminative image areas utilized by a CNN to recognize a certain image class. Grad-CAM utilizes the class-specific gradient information flowing through the last convolutional layer of a CNN to generate a coarse localization map of the image's significant areas. Grad-CAM may be used with current pixel-space visualizations to provide a high-resolution class-discriminating visualization. Grad-CAM does not need retraining and is suitable for all CNN-based designs [18].

The remaining section provides an overview of the related work in computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches.

Peng et al. [19] examined the role of AI in suppressing Coronavirus and divided their studies into three main categories: prediction, diagnosis, and development. When there is no solution to eradicate Covid-19, it is beneficial to predict the spread pattern of the virus so that preventive measures can be taken in high-risk areas. DL methods can help discover pharmacotherapy and Covid-19 vaccines with various chemical and pharmacological compounds. Also, predicting the survival rate of coronavirus patients by estimating the extent of damage to the principal organs of their body can help adopt a policy to combat Covid-19. Therefore, AI and other related technologies predict virus propagation, drug discovery, and survival rates. In this article, the authors examined the methods of diagnosing the disease through medical images, including CT and X-Ray, which have significantly improved the speed and accuracy of screening using neural networks (NN). It is almost impossible to assess and test many suspects using traditional methods and human resources in an epidemic.

Table 3 Definition of metrics used in this study

Metrics	Definition
Accuracy	It measures the precision with which samples can be classified as abnormal or normal
Sensitivity	It evaluates the model's capability to predict each available category's true positives and the relevant instances' proportion among the retrieved instances
Specificity	It evaluates a model's ability to predict the true negatives of each available category
F-measure (f-score)	It indicates a model's accuracy on binary positive and negative classification systems
Precision	It is the proportion of relevant instances among those that were retrieved
Recall	A fraction of the retrieved items indicate how accurate the retrieval is
MCC	It measures the difference between the predicted and actual values in the statistical evaluation of the model
ROC	It shows the performance of a classification model at all thresholds of classification
MAPE	A statistical criterion for measuring the accuracy of prediction models based on a formula
RMSE	It is the square root of the mean of the squares of all errors
Contact rate	It is a level of contact among people
Contact duration	It refers to the amount of time spent at a specific distance from another individual
Contact distance	The distance between two people during physical contact
Infection rate	It indicates the amount of Coronavirus present in the infected individual's body
Reliability	It is determined by the ratio of error messages to total messages
Energy consumption	It refers to the total amount of energy consumed during an activity
CPU-load	It refers to the amount of computational work that a computer system performs
Cohen Kappa	The agreement score compares several items grouped into mutually exclusive categories

Therefore, ML methods can learn and evaluate medical images with pre-prepared datasets. Intelligent diagnostic systems accurately and quickly identify the type and severity of the disease after identifying the symptoms and classifying the images. In another part of the study, they examined the role of AI in drug development by smart repositioning drugs. They also noted that this field of science helps accelerate the discovery and production of vaccines, forecasting the immune system to these compounds at a lower cost. AI and other technologies will also develop applications for telemedicine, monitoring, and tracking suspected and infected individuals. This article mentioned some of technology's positive features, such as speed, accuracy, processing, and storage capacity, and limitations, such as lack of datasets and false-negative or erroneous diagnoses.

Nasajpour et al. [4] investigated the role of IoT in combatting Covid-19 in the main three phases: diagnosis, quarantine, and recovery. They study the existing IoT technologies based on their application in different stages of Covid-19 and thoroughly evaluate their advantages and disadvantages. They do not mention the role of AI next to IoT. Security is also a significant challenge that they did not address in their article.

Aman et al. [6] first described the IoT ecosystem and the differences between traditional and modern medical systems. They compared three common types of architecture for IoMT and described its different layers. They examined the role of the IoT in the last three pandemics SARS-CoV (Asia) in 2002, MERS-CoV (Middle East) in 2012, and the Ebola epidemic (West Africa) in 2014, which, due to the limitations of technology, are not comparable in importance to its role in the Covid-19. They surveyed three countries, Taiwan, South Korea, and Germany, regarding their approaches to tackling the pandemic crisis based on their IT infrastructure. In IoMT, maintaining data integrity, confidentiality, and security is a significant challenge. The authors carefully identify the vulnerabilities and attacks on this system. Although this article takes a relatively broad look at the IoT and its relationship to other technologies such as AI and big data in Covid-19, it does not do a thorough study.

Jahmunah et al. [10] focused on IoT technology coupled with DL methods to prevent Coronavirus transmission. They propose an intelligent tracing tool that includes various wearable devices and phone applications to gather health data from vast areas. In their suggested structure, a server is connected to an AI-based visualization system to analyze collected data and identify data patterns to predict Covid-19. In this way, they cope with security challenges by decentralization, but this scheme includes different devices that need to be integrated. Although real-time monitoring is a positive point, it is a voluntary system, which is not accurate enough. The weakness of this system is noticeable energy consumption, and the bandwidth of the current types of networks is becoming less for that.

Dong and Yao [20] proposed a platform combination of IoT and fog-cloud divided into four layers to combat Covid-19 in five contexts: diagnosis, monitoring, tracing, forecasting, and virus mutation tracking. The perception layer comprises IoT devices for collecting data, the network layer for transmitting data, the fog layer for performing real-time and straightforward computations and analysis, and the cloud layer for performing complex analyzes using advanced AI. Their studies were categorized into sensor-based monitoring and data-based prediction, and they prepared several non-pharmaceutical interventions to cope with Covid-19. The layered structure introduces symptom diagnosis, quarantine monitoring, contact tracing, and social distance in the fog environment. Disease prediction and virus mutation prediction are two non-pharmaceutical interventions in the cloud layer. Through this categorization, they discuss IoT technologies utilizing DL and offloading tasks. In the hierarchical architecture of IoT, sensors are in the perception level in the form of (a) personal devices such as smartwatches, wristbands, and intelligent belts. (b) Smart homes and buildings such as fire extinguishing sensors, automatic heating systems, and remote control of home appliances. (c) hospitals: monitoring and diagnostic equipment. (d) Outdoor environment: urban traffic cameras, pollution, and sensors. The network layer includes communication technologies for the cellular Internet, satellites, and radars. Besides protocols, all types of hardware devices such as access points, routers, and switches are in this layer. The fog layer is between the cloud and the end-user to control the load. Fog nodes in this layer perform some simple computation without sending it to the upper layer. So it reduces latency and employs load balancing. Fog nodes do not have robust servers with heavy computing capabilities. Therefore, simple tasks such as tracking and monitoring social distance, identifying symptoms, and quarantine surveillance that does not have complex calculations are performed in this layer. The complexities of data analysis, classification, dataset identification, and DL system training are in the cloud layer. Massive data centers with multiple and powerful resources are securely in this layer to hold vast volumes of data. It is noted in the study that the proposed platform can analyze all biological characteristics of the virus. Despite this, the authors do not offer a method or tool for predicting the mutation pattern of a virus.

Albahri et al. [21] investigated the role of AI in accelerating and facilitating the identification of Covid-19 from medical images. CT scans and X-rays are effective methods for identifying symptoms of infection and diagnosing Covid-19 in its early stages. The spread of pandemics and the myriad of patients increased the need for physicians and specialists to diagnose infection from medical images. This necessity emphasizes using AI techniques in medical image classification to analyze intelligently. Plus, high accuracy in diagnosing and reducing the workload of treatment staff, and reduced decision time are other benefits of using this technology in controlling the pandemic. In evaluating and benchmarking medical images, multiple evaluation criteria, the importance of an index in each technique, and the trade-off between these criteria cause complexity in choosing the appropriate method for classifying medical images. Thus, multi-criteria decision analysis (MCDA) offers an excellent solution to these dilemmas. They studied classification methods in four categories: binary, multiclass, integrated binary, and multiclass, and hierarchical binary and multiclass and examined them by two types of data. A primary data set is gathered during the research process and approved by the relevant committee. The second one is available to the public online, called secondary data. All datasets are CT-scan and X-Ray cases. After reviewing all the methods of selecting the best classification technique and examining their advantages, disadvantages, and differences, no suggested solution that is superior to others was mentioned, which is the challenge facing the World Health Organization. The study authors recommended that medical centers determine first their evaluation criteria and calculation method before selecting a classification method based on these criteria.

Bhattacharya et al. [22] examined the role of DL techniques in processing medical images to combat Covid-19. They mention that control of the Coronavirus depends on early detection and prevention of transmission of the virus to others; despite the high accuracy of RT-PCR, time-consuming and the need for reagents led to the use of medical images as a standard diagnostic method. CT scan is preferable to an X-ray because it is three-dimensional. However, fast processing of these images in the traditional way is impossible in critical situations. Because the number of requests for imaging is very high and processing these images requires many experts. Accurate diagnosis and immediate decision-making about the patient's condition are necessities of the current situation, which AI has achieved. The accuracy and speed of DL in medical image processing for corona detection motivated the authors of this study. DL, like NN, can learn from context and adapt to different types of data, which has led to their spread in many areas, such as processing and extraction of features. It mimics the human brain's learning process by filtering input data, classifying, predicting, and providing feedback to the next layer. Learning occurs when feedback is provided continuously to different layers. This study examines the applications of DL surveys in five categories:

classification, localization, detection, segmentation, and registration. As part of the classification, one or more image samples are considered inputs to a CNN, whose output is a detection factor used to classify the images. The localization process is an essential step in detecting disease from an image.

An image segmentation process consists of decomposing a digital image into several fragments to simplify detection by technicians. There are challenges to using DL in medical image processing to combat Covid-19 due to the absence of large datasets. Image registration integrates datasets from various medical resources worldwide to tackle this problem. The authors discuss DL applications in epidemic prediction, the tracking of virus spread, diagnosis and treatment, and the development of vaccines and drugs. In the case of studies, Korea, China, and Canada's approach to using DL to control Covid-19 are surveyed. They also identify challenges, including massive dataset shortages, enormous processing power requirements, variant test methods, similarities between pneumonia and corona symptoms, privacy, and government policies. Finally, incorporating DL, image processing, biomedicine, data science, and mobile connection is mentioned as future work.

Table 4 summarizes the related studies on computer-aided methods for combating Covid-19 in prevention, detection, and service provision based on survey papers and SLRs. The study title, review type, main topic, publisher, publication year, and covered years are included.

The following issues must be addressed through a suitable literature review due to the limitations of existing studies:

- Most studies lacked a systematic approach to computer-aided methods for combating Covid-19.
- Existing studies all focused on a specific subset of computer-aided methods/technologies for combatting Covid-19.

3 Research selection

An SLR-based review is presented in this section, which evaluates research studies and reports on computer-aided methods for combating Covid-19 in prevention, detection, and service provision. The following search string is defined by adding substitutes and other synonyms to the keywords:

("prevention" OR "detection" OR "diagnosis" OR "service composition" OR "service provision") AND ("Coronavirus" OR "Covid-19" OR "pandemic") AND ("computer-aided" OR "computer-assisted") AND ("IoT" OR "Internet of things") OR ("survey" OR "review" OR "overview").

Numerous studies on Coronavirus have been performed since 2020 till now. To begin our study, we searched the above strings in the title, abstract, and keywords of articles in four databases (Elsevier, Springer, IEEE, and John Wiley). We selected the most relevant articles based on the inclusion and exclusion criteria described in Table 5.

Figure 2 illustrates the process of searching electronic databases, identifying articles containing keywords, applying filters, refining, and selecting final articles.

The systematic review provides detailed answers to the following Analytical Questions (AQ) under the scope and objectives of the proposed study:

- *AQ 1* Which domains are involved in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?
- *AQ 2* What are the evaluation environments, and datasets used in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?
- *AQ 3* Which evaluation metrics are used in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?
- *AQ 4* What future research directions should be pursued in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?

Since the outbreak began late in 2019, most articles have been published since 2020. All articles in our analysis were published between 2020 and 2023, apart from computer infrastructure technology. Figure 3 represents the publication trends of articles during these years and the distribution of articles within various publications.

4 Organization

This section aims to provide a technical review of selected papers using the SLR method. Figure 4 shows a taxonomy of computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches.

4.1 Prevention

Since no drugs have yet been developed to treat Covid-19 and the vaccine has not eradicated the disease, prevention might be an excellent way to control the spread of the disease. Studies of infectious diseases, particularly Covid-19, gradually transitioned from a detection approach to a prevention approach because communities have adapted to epidemic circumstances, and lifestyles have normalized. Many studies have focused on high-risk individuals and

Table 4 Some related studies on computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches

Research	Review type	Main topic	Publisher	Publication year	Covered years	Taxonomy	Open issues and future directions	Application	Advantage	Disadvantage
Peng et al. [19]	Review	Covid-19 detection, prediction, and development rely on AI	Springer	2022	Until 2022	Presented	Presented	Covid-19 diagnosis, prediction, and development	Focused on IoT, cloud computing, blockchain platforms	It lacks a systematic approach
Nasajpour et al. [4]	Survey	Control stages of Covid-19 using IoT devices	Springer	2020	Until 2020	Not presented	Not presented	Covid-19 identification, health monitoring in quarantine time, and the ability to follow a patient's recovery	Focused on smartphones, wearable devices, drones, robots, and IoT devices, IoT buttons	Only focused on IoT devices It lacks a systematic approach
Aman et al. [6]	Review	Application of IoMT in Covid-19	Elsevier	2021	Until 2020	Presented	Not presented	Security and big data analytics	Focused on applications, architecture models, and security simultaneously	Not focusing enough on AI algorithms It lacks a systematic approach
Jahmunah et al. [10]	Review	Integration of DL and IoT tracking tool	Wiley	2021	Until 2020	Not presented	Presented	Contact tracing and prediction	Focused on smartphones, wearable devices, drones, robots, and IoT devices	Only concerned with IoT devices and the deep learning algorithms It lacks a systematic approach
Dong and Yao [20]	Survey	Fog-cloud tracking platform for Coronaviruses mutations	IEEE	2021	Until 2021	Not presented	Not presented	Covid-19 prevention and control	Focused on fog-cloud-IoT platforms	Not focusing enough on AI algorithms It lacks a systematic approach
Albahri et al. [21]	Systematic review	Applying AI to the classification of Covid-19 medical images	Elsevier	2020	Until 2020	Presented	Not presented	Classification and identification of Covid-19 medical images	A systematic methodology for the analysis of AI algorithms for the classification of Covid-19 medical images	A straightforward taxonomy is presented A survey that is a bit out of date

Table 4 (continued)

Research	Review type	Main topic	Publisher	Publication year	Covered years	Taxonomy	Open issues and future directions	Application	Advantage	Disadvantage
Bhattacharya et al. [22]	Survey	Covid-19 diagnosis accelerated by DL image processing	Elsevier	2021	Until 2020	Presented	Presented	medical image processing	Comprehensive survey	Focused only on deep learning applications, and medical image processing
Our study	Systematic survey	Covid-19 in prevention, detection, and service provision approaches		2023	Until 2023	Presented	Presented	Covid-19 prevention, detection, and service provision approaches	Concentrated on IoT, fog-cloud computing, using AI, machine learning, deep learning A comprehensive and systematic survey	-

areas and adopted prohibitive policies and enhanced prevention methods in the last year. Consequently, most of our reviewed articles under the prevention approach were published in 2021 and 2023, whereas in 2020, most of our studies focused on detecting computer-based technologies for automatically diagnosing diseases. The computer-based prevention approach includes identifying infected people, monitoring their health status, tracking their close contacts, and alerting them. IoT, including vital sign sensors, thermal cameras, trackers, smartphone applications, and cloud-based technologies for transmitting, storing, and analyzing big data and computer networks for transmission, plays a critical role. Branches of computer science, especially AI, such as DL, computer vision, and object detection methods, are beneficial in advancing this approach. This review discusses several papers published using the prevention approach to control Covid-19, their challenges, proposed solutions, methods, and future research. This section contains a third of our referenced papers.

Garg et al. [23] developed an IoT-based contact tracking model for controlling Covid-19 that uses the concept of blockchain to maintain privacy. Researchers worldwide have studied various approaches to coronavirus detection that generally do not involve moving objects and animals that can also carry the virus. The authors suggested using a proof-of-concept RFID transceiver to trace non-human infected objects. This article describes four current contact tracking approaches to controlling Coronavirus outbreaks: applications available from mobile service providers, information from mobile network operators, applications for citizens, and IoT-based solutions like wristbands and video surveillance. Others receive alerts as soon as they approach these tagged people. They implemented the model with three prototype blockchain smart contracts and simulated deployment and function calls. They evaluate call time and deployment cost with the Remix IDE simulator, and the results show that their model is more efficient than others. Researchers can add RFID to this model in subsequent studies and make it more scalable and cost-efficient.

For patients with mild symptoms quarantined at home, Sicari et al. [24] provided a system for remote monitoring employing IoT technology. The system consists of wearable devices, sensors for measuring air quality, a light database, and a monitoring dashboard. Clinical data are collected by sensors worn by the patient, such as temperature, blood pressure, oxygen saturation levels, heart rate, and respiration rate. Additionally, as ambient air quality is critical to improving lung function in patients with Coronaviruses, sensors are installed to alert if air quality indicators are abnormal. A GPS also alerts the medical staff when patients leave the quarantine zone. MongoDB, a lightweight database, stores, and updates all data. A

Table 5 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
High cited articles	Articles on the economic and social impacts of Covid-19
Articles on Covid-19 technical infrastructure	Invited papers, letters, and conference papers
Articles related to computer science	Medicinal, chemistry, and psychology articles
Articles on service computing, meta-heuristic algorithms, and cloud computing	Irrelevant content

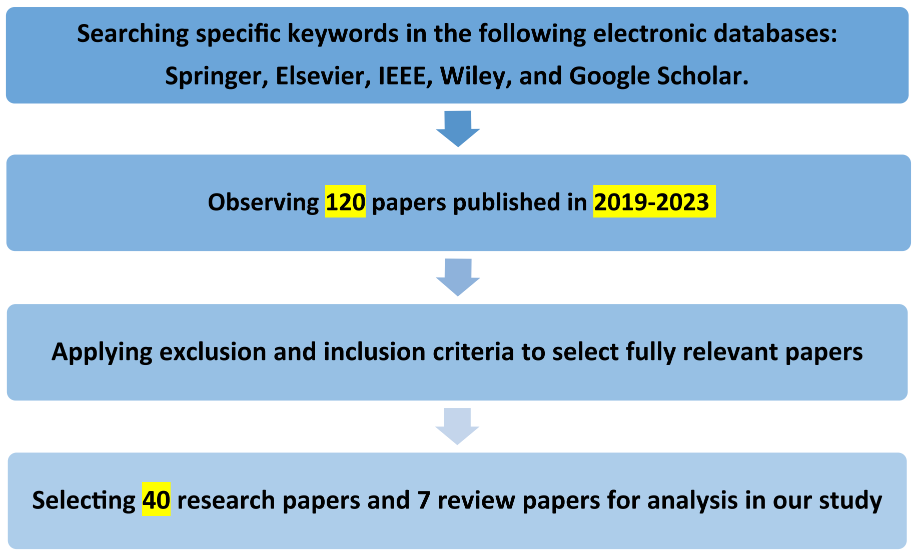

Fig. 2 The selection process of papers

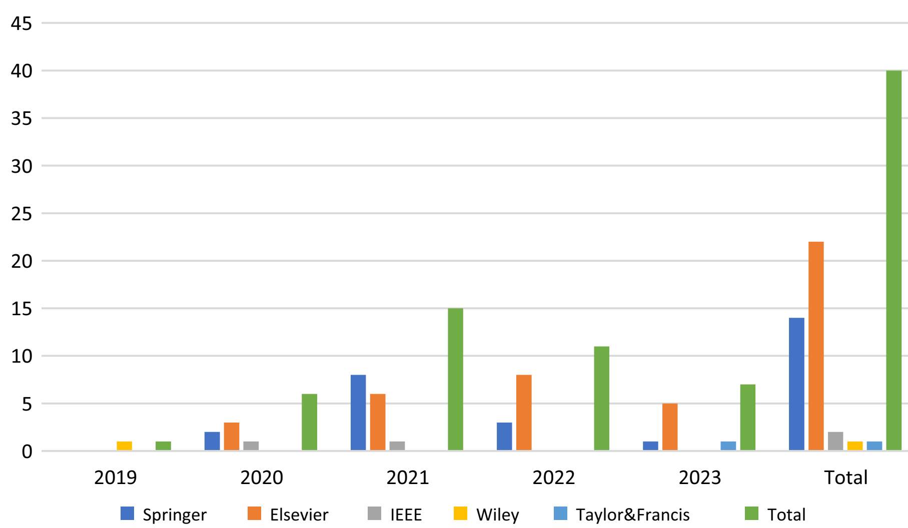

Fig. 3 The distribution of papers by publishers and publication year

dashboard is also available for tracking changes, viewing alerts, and monitoring patient status. This article provides an overview of remote surveillance architecture for architectural designers. All patient data are encrypted with Node-RED CryptoJS to ensure privacy and security. The proposed scheme is simulated using Node-RED, written in Java code. They suggest that the proposed system be improved to monitor patients on a larger scale and provide more visual alerts. It is possible to estimate the average number of patients based on their location. This study did not discuss the distinction between lost and redundant data in this system, which future researchers can consider.

Bhatia et al. [25] presented a framework using fog-cloud and IoT technologies to monitor Coronavirus-infected patients remotely. Wearable sensors continuously monitor physiological data, including temperature and blood

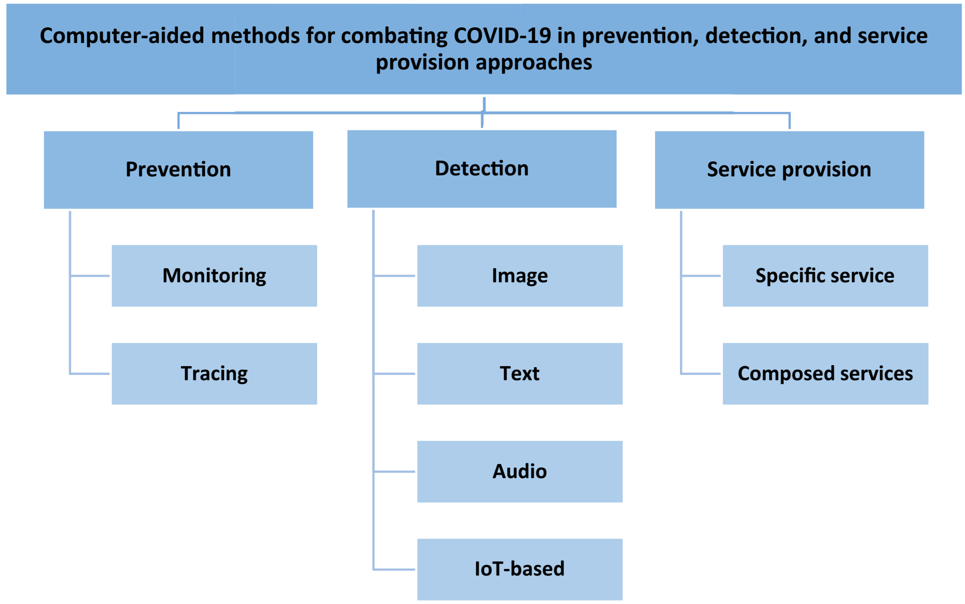

Fig. 4 The taxonomy of computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches

pressure, to identify viral infections when abnormal changes occur. However, providing large volumes of real-time information is a significant challenge. They overcame it by utilizing the concept of fog at the high level of the cloud. The proposed framework uses RFID technology to determine how users interact, Temporal Network Analysis (TNA) to track people, and the J48 decision tree to determine the degree of infection in a patient's body. The temporal Proximity Index (TPI) is a method of identifying infected individuals and places. They presented a layered architecture, including sensors and RFID tags interconnected through WiFi, Zigbee, and Bluetooth. Accumulated data from these nodes are sent to the fog layer for classification by the J48 algorithm. All data processed in the second layer are transmitted via 3G/4G and WiFi to the third layer, where the cloud storage is located. Network temporal analysis and vulnerability assessment at this layer are performed, and the decision results are sent to the next layer for the medical team and users to monitor. The advantage of this design is that the data are real-time, and the cloud and fog have created almost unlimited storage space. The authors created synthetic data to evaluate the effectiveness of this framework based on 2500 users in the Amazon cloud storage service.

Moreover, they evaluated the performance of various classification methods, including Random Tree, Naive Bayes, and REPTree, using Weka 3.6. Metrics such as accuracy and sensitivity demonstrate the efficacy of this framework, while delay, precision, and F-measure demonstrate the fog-cloud-based quality of the analysis. The proposed framework can be further developed by adding the capability of inserting lost data in future work.

The current context of the Covid-19 disease emphasizes the importance of controlling and preventing the spread of infection throughout the community, particularly in areas with high population flow rates such as airports. Thus, Wu et al. [26] utilized computer vision and object detection to provide an automated monitoring framework to detect how to put on a mask based on facial recognition. The authors implemented the Face Mask Detection-You Only Look Once (FDM-Yolo) algorithm, including feature extraction, feature fusion, and post-processing techniques. Based on recall and precision parameters, they evaluated this algorithm against eight well-known DL algorithms using two public datasets (MD-2[1] and MD-3[2]). The first database contains three categories of images: faces without masks, faces with masks, and incorrectly masked faces. There are three categories in the second database: faces without masks, faces with masks, and incorrect masks worn by faces. These devices receive video streams and images, pre-processing them before separating the training data from the validation data and removing dirt. The mask wear status is displayed on an output device, such as a mobile phone or laptop. As a result of the evaluation, FDM-Yolo is superior. Accordingly, the proposed framework plays an essential role in preventing the spread of the disease by detecting and controlling those who fail to wear the mask properly.

Castiglione et al. [2] developed an IoT-based framework to decrease the disruptive effects of a pandemic by monitoring and controlling Coronavirus in four stages: collecting disease symptoms with IoT devices, monitoring patients in innovative health centers, analyzing collected data by using ML, and providing medical advice to patients. It is possible to control the latest pandemic with the help of IoT sensors found in gadgets, homes, hospitals, and cities. Additionally, drones and robots provide medical services, disinfection, and air surveillance. In this paper, the authors mention some challenges associated with IoT, such as scalability, bandwidth limitations, privacy, and data transfer issues. During the data analysis stage, they applied five machine-learning models to determine which machine-learning model is the most efficient regarding classification. The evaluation results indicate that random forest (RF) is the most accurate method for identifying the severity of an infection. Future studies should use real-time tools to enhance their efficiency.

Otoom et al. [27] proposed a system consisting of data collection, a physician, a quarantine center, and a data analysis center to identify suspected Coronavirus cases and monitor them. In this system, data are collected by voluntary wearable devices; therefore, the data set is not accurate enough. In contrast, implementing a unified policy and enforcing it across all areas under study would provide a specific dataset and solve this problem. The authors evaluated their idea by assessing the performance of eight ML algorithms and comparing them based on four parameters: accuracy, root mean square error (RMSE), F-measure, and the receiver operating characteristic (ROC) area. In this system, doctors and quarantine and treatment centers are also equipped with IoT devices, and Internet-based communication helps avoid the spread of the virus. If it overcomes the challenge of providing a comprehensive and correct database, the proposed system can identify the nature of the virus by analyzing data on those infected and recovering. It would be helpful to integrate data from various valid sources worldwide through DL techniques in the future and complement this study.

In most regions, the lack of quality thermometers causes oral thermometers to be used instead, which increases the risk of Covid-19 spreading. To identify potentially infected persons (PIPs) to Covid-19, Barnawi et al. [2] proposed developing a UAV equipped with a thermal camera to measure body temperature and an ordinary camera to detect faces at an urban scale. They utilize a face detection model to identify suspect individuals, locate them using their unique ID, and alert their mobile applications. The model can determine whether the intended individual wears a mask. In Edge infrastructure's speed and processing, power help improve real-time extensive data analysis captured by onboard sensors and reduce response time. Establishing thermal screening models in high-traffic areas like hospital entrances can help prevent infection. The thermal camera mounted on the UVA records video to identify people with high temperatures, and the ordinary camera records video for face detection. The authors use two different datasets and ML and DL techniques to train and test face and mask detection models. The object detection technique distinguishes humans from other objects in this system, and individuals with high body temperatures are identified. Video recorded by the ordinary camera is examined for face detection. After matching the person's face with the ID, appropriate alerts are sent to their phone application to register their information. The proposal is finally evaluated with six performance metrics to assess its practical feasibility in a real-time scenario: Accuracy, Precision, Recall, F1-score, Cohen's kappa, and ROC accuracy. The proposed scheme can only be used for outdoor temperature screening. Nevertheless, it has a good effect on controlling the spread of the virus. In the future, indoor temperature screening may be investigated.

Al Bassam et al. [28] developed an IoT-based layered system comprised of sensors, the cloud, and mobile applications, to manage Covid-19 outbreaks. In the first layer, sensors are placed on the individual's ankle, hands, and neck. The sensors provide body temperature, heart rate, blood oxygen levels, cough patterns, and location. Cloud storage is provided at the second level, along with a web-based application peripheral interface (API) that integrates a firewall to secure databases. Sensor data are sent from the microcontrollers to an API accessible to medical authorities. The third component is an Android application that receives notifications, alerts, and preventive measures via SMS and email. Each of these units is synchronized, and the patient's health status is updated every minute. As a result of IoT and DL, much data can be recorded to track symptoms. They use a basic system for measuring physical symptoms such as temperature, oxygen, and heart rate, and the respiratory system for measuring and diagnosing coughs. In response to the audio sample collected by a sensor, and after separating noise from cough, AI models extract features along with MFCC. They then train and test them with CNN. Some of the benefits include considering system security in the cloud and application layers, selecting light and minor hardware, applying AI methods for accurate detection, transmitting real-time information, and implementing web-based and mobile systems. However, the lack of compatibility with other mobile operating systems is one of the deficiencies of this plan, which can be implemented in the future. They noted that this system would provide passengers with better protection at the airport and on flights in the future.

In a crisis such as the Covid-19 pandemic and the need to reduce contact between individuals, IoT is increasingly important, especially in the health area. In this article, Pongudi et al. [29] proposed controlling the spread of Coronavirus by utilizing IoT for tracking infected individuals. They use graph theory to show individuals as nodes and their contacts as edges of a graph. In this system, people are equipped with intelligent sensors such as wearable devices. Sensors record health data and send it to a central server with medical records from hospitals. The system identifies infected and exposed people by evaluating symptoms in integrated health data in the central server. The presence of symptoms such as fever, cough, and fatigue indicates whether or not a person is infected. Nodes and edges are updated periodically based on severity, duration, and distance of contacts. Then, alert signals are transmitted to cell phones, and appropriate instructions, such as quarantine or isolation, are provided to the affected individuals. Real-time data transmission in the cloud environment on both device-to-device (D2D) and 5G is one of the advantages of this system that results in fast decision-making and low power. The authors simulate their system with Python. The results are accurate due to simplicity. They suggest extending the idea on a large scale and in detail to become a product to use in the real world in the future.

Viral diseases can be prevented by rapidly identifying suspicious individuals and taking measures to monitor their health status. This will ensure that, in case of infection, they and those in close contact with them are monitored. The speed of testing for infectious diseases and the disclosure of the results to the public is paramount. Wolfinger et al. [30] introduced the contagious disease testing problem (CDTP) and used the large neighborhood search metaheuristic algorithm as a solution. The investigators of this study examined two sets of mobile and fixed samplers and evaluated all potential solutions, including the number of sampling stations, the assignment of samples to laboratories, and the most efficient routes to diminish time and costs. The authors incorporated linear programming and the C + + programming language to address the issue involving mixed numbers. Comprehensive studies were done to examine the solution, and the findings indicate an advancement in efficiency, time, and cost. It is necessary to consider the dynamic environment of reality as a limitation of this study and future work.

Virus transmission rates in the community are influenced by numerous factors, including contact characteristics, age, and population behavior. In a study, Hosseini-Motlagh et al. [31] formulated some of these factors to minimize the rate of virus transmission. They use the MSFP approach to consider uncertainty and divide patients according to their age and allocate healthcare facilities according to their severity. By using this model, decision-makers can decide based on optimism and pessimism. This model was implemented on real case data in Tehran, Iran, using GAMS software. Following several analyses indicating the efficacy of the model, it has been confirmed that the elderly population has the greatest impact on Coronavirus transmission. Future studies should consider asymptomatic cases, mortality rates, and discharge rates, as well as the robustness of the proposed model.

Chen et al. [32] proposed a framework for adopting sufficient social distancing policies based on a mathematical model and evaluating economic and health consequences. This study aims to improve social distancing to minimize deaths caused by Covid-19 using deep learning, two heuristic algorithms, and a SIRD mathematical model with big data analysis from Google on real data from the USA to investigate the mobile indicators of society, which can be applied in any country in the future. It is also possible to use this model to simulate future scenarios to examine the effectiveness of social distancing policies in the future. In addition, there are limitations to this study, as they constructed it at a fixed ICU rate and did not consider disease severity or age as subcategories. It is important to note that a mathematical model based on constant variables will not be effective for all governments. Therefore, each government should develop a model tailored to its needs.

The discovery of the vaccine allowed the epidemic to be controlled by tracking people's vaccination status and providing citizen services accordingly. Pradhan et al. [33] developed a framework for tracking vaccinations using artificial intelligence, blockchain, and Ethereum Virtual Machine (EVM), which offers the advantages of decentralization of data, reliability, privacy, availability, verifiability, and integrity. They implemented the proposed framework using the Truffle and Ganache tools and then, evaluated it based on latency, throughput, traffic, CPU, and memory consumption.

A significant factor in preventing the transmission of the virus, both during and after the outbreak, is to avoid unnecessary contact. Accordingly, Saraswat et al. [34] introduced a contactless attendance system to replace the traditional biometric system. There are several advantages to this plan, including anti-spoofing, a one-time entry system, efficiency, and cost-effectiveness. Lastly, they evaluated their proposed system based on image precision, cost, retrieval latency, and anti-spoofing capabilities which proved very high accuracy and cost savings through the use of the Firebase database.

4.1.1 Analysis of studies in the prevention approaches

As part of this subsection, we review the papers on the prevention approaches and a summary in Table 6.

Considering that each paper uses some criteria to evaluate its method(s), we have listed and defined all the evaluation metrics used to analyze the prevention approaches in Table 7. It demonstrates that most authors evaluated the Covid-19 prevention approaches using metrics such as accuracy, f-measure, and precision.

4.2 Detection

In the early days of the Coronavirus outbreak, there was not much knowledge about how the virus behaved, including how it was transmitted from environment to person or person to person and even the human body's reaction when the virus entered it. The similarity of the symptoms of this disease with pneumonia and other infectious diseases sometimes leads to misdiagnosis. On the other hand, in pandemic conditions, the number of patients is enormous, and medical staff is limited. Thus, in exceptional circumstances, automated diagnostic systems that can prepare a large volume of medical samples and images, determine symptoms, and diagnose the disease with a minimum of human intervention are beneficial. The high number of patients makes it difficult to diagnose the disease and provide treatment services accurately. Therefore, researchers and scientists of different sciences have been collaborating to study and improve approaches to prevention, diagnosis, and service to society using methods based on computer science. A few of the services that computer science provides to human society for epidemic control include, for example, the use of heat cameras to take aerial photographs of large areas and to identify high-risk areas, the use of intelligent robots to collect samples from patients' throats and mucous membranes, the use of intelligent imaging devices to control technician distance, the use of AI diagnosis and DL, and the delivery of drugs and chemotherapy in the shortest possible time to patients' requests with the help of optimization algorithms. Since the Coronavirus outbreak, numerous studies have been conducted on computer-based self-diagnosis, and we have reviewed the most critical challenges, techniques, and solutions studied with a diagnostic approach. Most of the articles we selected in this area were published in 2020 and 2021. These are also a significant number. We focused on the prevention and service approach. Therefore, approximately 48% of the articles are included in this section.

4.2.1 Image-based detection of Covid-19

Nasser et al. [35] proposed a Covid-19 detection system integrated with IoT and cloud technologies. IoT devices send patient information, including a CT scan image, to a cloud server containing a diagnostic model in this system. The data are classified based on DL models previously trained using two public Covid-Chestxray and Chex-Pert datasets and the ResNet50 CNN model. The system makes real-time decisions based on the patient's health status. It also provides intelligent recommendations on the facilities needed by the patient and tracks them. This model has been evaluated through cross-validation using performance metrics such as accuracy, sensitivity, specificity, and F1, and the results show that this model is superior to existing models. In this study, some shortcomings can be improved in future work. For example, the proposed healthcare system uses CT-scan images as datasets, which have shortcomings compared to X-ray images. This system only can distinguish infected people from healthy ones. Sometimes the infection is not caused by Covid-19, and the unhealthy person may have another infection disease such as pneumonia, which leads to misdiagnosis followed by inappropriate advice. The authors could use fog technology instead of cloud to reduce network traffic and the cost of data transfer to the remote cloud and cover the low computing and storage capacity of the IoT devices by this technology. It is not cost-effective to use cloud technology when it does not require a huge processing capacity. Data can be processed and analyzed in local fog hubs and integrated into a cloud server to control network traffic and reduce the cost and delay of transferring data to the cloud. Although one of the authors' concerns in this article is to reduce patient costs, it did not consider the cost of data transfer to the cloud.

A high prevalence of Coronavirus increases the need for chest images that are difficult to analyze without AI. Laxmi Lydia et al. [36] developed a federated DL-based model that takes advantage of mobile edge computing (MEC) for diagnosing Covid-19; they called it FDL-Covid (federated DL-based Covid-19). The IoT collects data while AI handles classification, pattern identification, and disease diagnosis. However, there are also challenges: Firstly, the amount of data collected by IoT is immense, and ML models are required to organize it. Additionally, large amounts of data are necessary for the use of intelligent analysis to train a system; however, healthcare providers, physicians, and patients do not wish to share medical records. The federated learning (FL) system integrated disparate data worldwide, trained those modules on a central server, and re-distributed the updated modules. Since raw data on local clients (clinics) are never exchanged during these processes, privacy is guaranteed. In this study, Glowworm Swarm Optimization (GSO) algorithm is used to optimize the hyperparameters of the dataset for classification by SqueezNet DL. The dataset is divided into normal, pneumonia, and Covid-19. The model proposes identifying which chest X-ray images are placed in the Covid-19 class. The use of network-edge technology and IoT can reduce network traffic, latency, and costs associated with data transfer to the remote cloud. This method also addresses privacy issues and the lack of training data in DL. In the future, resource management and offloading may be improved.

Pneumonia is a common complication of most infectious diseases. The correct diagnosis of pneumonia caused

Table 6 The classification of studies in the prevention approach

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Garg et al. [23]	Developing a contact tracking model based on IoT and blockchain technology to control the Coronavirus spread	Scalability Privacy Time-efficiency Cost-efficiency	Not scalable	Cost Time	Implementation (three prototypes) Simulation (Remix IDE: a web-based testing environment for Ethereum blockchains)	Maintaining privacy with blockchain in IoT	Designing an RFID-based front-end application Scaling up this solution Lowering costs
Sicari et al. [24]	Remote monitoring of quarantine patients using IoT	Prevention of Coronavirus spread by mild symptoms patients Active monitoring Preserving privacy	Not distinguishing between redundant and lost data	Time CPU-load	Simulation (Node-RED: a tool for flow-based programming)	Integrating heterogeneous IoT devices Utilizing lightweight databases Active monitoring of mildly symptomatic patients	Designing an intuitive dashboard Scaling up the implementation Calculating the average patient count based on location
Bhatia et al. [25]	Monitoring framework based on fog-cloud, IoT, and RFID technologies	Time-sensitive High-capacity storage Identification of close contacts	Declining performance with increasing users	Accuracy Sensitivity Delay Precision F-measure	Simulation (Amazon EC2 cloud) Dataset (250,000 users generated synthetically)	Capturing real-time data Identifying close contacts Fixing storage problems	Restoration of lost data
Wu et al. [26]	An automated framework for detecting mask status on faces	Enhancing face recognition efficiency	No generalized for real-world situations	Recall Precision	Dataset (Two public datasets included images of different faces with and without masks)	Assessing the mask-wearing status of individuals using computer vision and object detection	-Incorporating this algorithm with self-attention in real-world scenarios
Castiglione et al. [3]	Developing a framework using IoT and ML to monitor Coronavirus	Accelerating detection Speeding up response times	Not real-time	Accuracy Precision Recall F-measure	Dataset (Covid-19 Symptoms Checker) Implementation (Python)	Analysis and classification of datasets using ML models	Real-world implementation

Table 6 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Otoom et al. [27]	An intelligent IoT framework using ML algorithms to identify and monitor Coronavirus-infected individuals	Speeding up the detection of suspicious cases Collecting real-time data Improve the understanding of the virus Increasing the accuracy and efficiency of identifying infected individuals	Not accurate data	Accuracy RMSE F-measure ROC	Dataset (CORD-19)	Collecting real-time data through IoT to detect Coronavirus early	Collecting random data
Barnawi et al. [2]	Combining body temperature screening with facial detection for identifying Covid-19-infected individuals	Increasing accuracy of Covid-19 detection Reducing response time Speeding up alarm Decreasing infection transmission rate	Inability to measure indoor temperatures with UAVs	Accuracy Precision Recall F-measure Cohens Kappa ROC	Dataset ("Labeled Faces in the Wild." training dataset)	Monitoring the body temperature of people outdoors with UAV-mounted thermal cameras	Saving time through online training Indoor thermal screening without collision
Al Bassam et al. [28]	Detecting and tracking potentially infected patients using an IoT platform	Decreasing the spread of the disease Enhancing control over a country's economy Reducing the stress associated with disease Increasing the quality of life	Not compatible with non-Android operating systems	Accuracy F-measure	Implementation Simulation	GPS and wearables to track Coronavirus infections and alert authorities	Use of the proposed model for airline passengers during travel

Table 6 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Pongudi et al. [29]	Tracking Covid-19 patients through IoT and graph theory	Simplicity Accuracy Real-time	Not being a real-world product	Severity Contact duration Contact distance Infection rate	Simulation (Python)	Utilizing graph theory and IoT to identify and track infected and exposed individuals	Creating a real-world product based on the original idea
Wolfinger et al. [30]	Presenting a meta-heuristic solution to solve the contagious disease testing problem (CDTP) for suspected Covid-19 cases to minimize costs	Extensive validation of the solution Saving time Minimizing cost Efficiency Cutting down on the number of samplers Minimizing the number of active sampling sites Accelerating the testing and preparation of the results	Non-consideration of the dynamic nature of the real situation	Efficiency Cost Time	Implementation (C + +) Dataset (Real data of two Austrian provinces)	Using a meta-heuristic algorithm to examine all paths through patients and testing centers Offering mobile sampling services for critical patients	Examining the CDTP in the dynamic environment of the real world
Hosseini-Motlagh et al. [31]	Coronavirus transmission rate calculation based on contact characteristics and optimal allocation of health facilities to patients based on severity and age to minimize the spread of the disease	Identification of transmission factors for Coronavirus Reduction in cost and time Improving efficiency in allocating healthcare facilities to patients Improving decision-making strategies	Not considering robustness Insufficient consideration of uncertainty	Rate of contact Duration of contact Transmission events per contact Vaccination Susceptibility to COVID-19 Protection degree Age	Implementation (GAMS software, Cplex solver) Real-world dataset	Calculating Coronavirus transmission rate based on various factors, such as age Optimal allocation of healthcare resources based on a patient's severity	Improving reliability by considering asymptomatic cases Enhancing performance by incorporating robustness into this model Consideration of the impact of different preventive measures on transmission rates Death rate uncertainty and discharge rate considerations

Table 6 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Chen et al. [32]	Providing a framework for determining optimal social distance policies considering both economic and health perspectives using mathematics	Minimizing economic fluctuations Consideration of both data availability and randomness Dynamics Efficiency	Unavailability of various unpublished datasets Disregarding the different infectious diseases Lack of sub-categorizing patients according to factors such as age	Infection rate Efficiency	Implementation (Keras in TensorFlow) Dataset (data related to the U.S COVID-19, Google mobility data)	Using big data analytics to develop community mobility solutions and machine learning algorithms to handle the pandemic -Using COVID-19 statistics to quantify economic impacts	Enhancing the model's accuracy Incorporating micro-perspectives, such as collective behavior, into the analysis Categorizing patients based on factors such as age or geographical location Assuming the market index Developing more sophisticated models
Pradhan et al. [33]	Tracking vaccination status framework using AI and blockchain technologies to control COVID-19 spread	Reliability Decentralization of data Synchronizing data Availability Verifiability Integrity Efficiency Privacy	Logging into the application is mandatory, but some users avoid doing so	Latency Throughput Traffic CPU Memory	Implementation (Truffle and Ganache)	Tracking vaccination status using blockchain technology in a decentralized and reliable manner	Taking advantage of vaccine cards to offer a range of services to people who are fully vaccinated
Saraswat et al. [34]	Camera-based contactless presence system with anti-spoofing capabilities	Scalability Cost-effectiveness Anti-spoofing mechanism Time efficiency	Incompatibility with IOS mobile application	Storage cost Retrieval latency Accuracy Precision Anti-spoofing analysis	Implementation (Python, Keras library)	Developing a contactless attendance system based on a camera to prevent Coronavirus transmission	Incorporating a transfer learning approach in this system Enhancing the accuracy of the marking system employing an Inception V4 network

Table 7 Comparison of factors involved in the prevention approaches

Research	Cost	CPU-load	Accuracy	Recall	Precision	F-measure	Sensitivity	RMSE	ROC	Cohens Kappa	Contact features	Infection rate	Time	Anti-spoofing	Efficiency	Vaccination	Susceptibility	Protection degree	Age	Throughput	Traffic	Memory
Garg et al. [23]	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Sicari et al. [24]	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Bhatia et al. [25]	×	×	✓	×	✓	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Wu et al. [26]	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Castiglione et al. [3]	×	×	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Otoom et al. [27]	×	×	✓	×	×	✓	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×
Barnawi et al. [2]	×	×	✓	✓	✓	✓	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×
Al Bassam et al. [28]	×	×	✓	×	×	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pongudi et al. [29]	×	×	×	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×
Wolfinger et al. [30]	✓	×	×	×	×	×	×	×	×	×	×	×	✓	×	✓	×	×	×	×	×	×	×
Hosseini-Motlagh et al. [31]	×	×	×	×	×	×	×	×	×	×	✓	×	×	×		✓	✓	✓	✓	×	×	×
Chen et al. [32]	×	×	×	×	×	×	×	×	×	×	×	✓	×	×	✓	×	×	×	×	×	×	×
Pradhan et al. [33]	×	✓	×	×	×	×	×	×	×	×	×	×	✓	×	×	×	×	×	×	✓	✓	✓
Saraswat et al. [34]	✓	×	✓	×	✓	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×
Total	3	2	6	3	5	5	1	1	2	1	2	2	3	1	2	1	1	1	1	1	1	1

by Covid-19 is therefore challenging. Pereira et al. [37] developed a method for distinguishing Covid-19 pneumonia from other pneumonia caused by different pathogens. In this study, the lungs are classified according to seven factors: normal, Covid-19, MERS, SARS, varicella, streptococcus, and pneumocystis. Of the 1144 CXR images evaluated for classification, 1000 images were related to healthy lungs, and 90 to Covid-19, and other diseases. Resampling is a method that corrects an imbalanced distribution of illnesses among datasets. Since texture is one of the most critical elements in CXR, the authors used well-known texture descriptors and pre-trained CNN models for classification.

Furthermore, they simultaneously utilize both early and late fusion techniques to utilize multiple texture descriptors. Their research focuses only on chest X-rays as the method of diagnosis for Covid-19 disease since it is more cost-effective and faster than other methods of diagnosis. The F-score of their classifications is measured in two ways: multi-classification and hierarchical classifications. Despite imbalances in the datasets, evaluation results demonstrate the highest rate of identification of Covid-19. Future works should include the analysis of a more comprehensive dataset and more sophisticated DL methods.

Innovations in IoT and 5G technology have improved health care applications in Covid-19. Le et al. [38] proposed a modified CNN named depthwise separable convolution neural network (DWS-CNN) that consists of four steps necessary to diagnose Covid-19. This system begins with data collection, where IoT devices collect images such as X-rays and transmit them to the cloud server for processing. Gaussian filtering is the second step, which eliminates noise from images. The primary function of CNN is to extract features, but in the proposed system, DWS-CNN will extract features automatically. As a final step, the deep support vector machine (DSVM) model labels the classes as binary or multiple. All these procedures are performed to achieve the maximum classification performance in Covid-19 for an accurate and intelligent disease diagnosis. The model is first trained and then tested. This paper presents a Python implementation of the proposed model. It evaluates its performance using a variety of CXR datasets with different labels, including SARS, ARDS, Covid-19, Streptococcus, and several normal images. According to the results, DWS-CNN can classify both normal and Covid-19 images. To evaluate the test, four criteria are used: sensitivity, specificity, accuracy, and F-Score, which are all more than 98 percent effective.

Ahmed et al. [39] proposed an IoT framework based on big data analytics techniques and DL methods to detect and predict Covid-19. In this framework, real datasets are collected from IoT devices and are used as input for four different types of big data analysis: descriptive, diagnostic, predictive, and prescriptive. Descriptive analysis is one of the most elementary types of big data analysis, in which detailed information such as features, attributes, and population size is derived from raw data sets. Here, the results of the descriptive analysis are represented by visual components such as pie charts, bar charts, and graphs, and humans can easily interpret that. In the case of Covid-19, the output of this analysis may include the number of tests performed, the patient's age, gender, health history, the length of hospital stay, and the number of recovered aces. Diagnostic analysis is an advanced form of big data analysis used to analyze relationships between attributes and features of descriptive analysis. It tries to interpret the cause of events and behaviors through a process known as data mining and data discovery. Diagnostic analysis can identify all the common symptoms of Covid-19. In predictive analysis, specific features of the data collected from prior analyses are selected for inclusion in DL models for training and testing. As part of predictive analysis, specific features of the data collected from previous analyses are given to DL models for training and testing.

Various metrics are used to evaluate this advanced analysis, and the final results are sent to physicians for additional examination. These professionals will determine whether the patient needs to be hospitalized, treated with medication, or treated with short personal care. All possible treatment measures and their potential consequences are considered during this process. This stage is valuable in terms of health care and controlling pandemic outbreaks. The authors evaluate F1-Score, accuracy, precision, and recall.

Moreover, ML models are compared with the NN model in the diagnostic analysis stage. In conclusion, the evaluation results demonstrate efficiency and accuracy in diagnosing diseases and speeding up the decision-making process for treatment. The necessary infrastructure for providing security, privacy, and integrity is not explored in this study but can be addressed in the following work.

4.2.2 Text-based detection of Covid-19

Covid-19 lung involvement can also be determined with textual radiological reports, PCR tests, and medical images (chest CT-scan and X-ray). Based on Natural Language Processing (NLP), López-Úbeda et al. [40] proposed an automatic detection system. This system integrates data from various resources, then selects the best features, classifies them to identify abnormal signs in chest CT reports of suspected Covid-19 cases, and automatically detects Covid-19 lung involvement. In this way, two sources of information supply the system's input: textual reports of chest CT radiology and abnormalities extracted by SNOMEDCT. All data evaluated in this study are obtained from the "HT m' edica" clinic. Therefore, the dataset of this study is not extensive and rich.

The authors used ML methods and Named Entity Recognition to train their text classification system. SVM performed the best training and highly competitive accuracy of several ML models. One of the most critical processes in this system is feature selection. Because by choosing the best set of features, they can give helpful surplus information to the ML system to make a more accurate classification. Their study surveyed three DL methods to empower the computation and availability of new data: long short-term memory (LSTM) network, bi-directional long-term memory (BiLSTM), and CNN. This study compares the results with well-known feature extraction methods such as term frequency-inverse document frequency (TF-IDF), TF, and MI-based methods to determine how effective it is. The evaluation results are presented based on precision, recall, accuracy, f1- score, and Matthews correlation coefficient (MCC). The advantages of this system are the accuracy and quality of forecasting and its cost-effectiveness. It is recommended to use various datasets in the future. Also, abbreviations and descriptive expressions should be processed to improve the system.

Lybarger et al. [41] developed the first model for extracting information from textual data using a neural event extraction end-to-end model to improve the diagnosis of Covid-19. Their proposed model is called Covid-19 annotated clinical text (CACT). Scattered data such as vital signs, exposure histories, laboratory test results, and routine annotation are found in clinical free texts. Description of chronic, underlying, and inherited diseases and important structured data are documented in patients' clinic medical records. There is also valuable information in electronic health records (EHR) that maybe include diagnostic symptoms of Covid-19. The world needs an automated data-based text extractor to use this vast amount of information to identify symptoms and improve Covid-19 recognition. This article is part of a more significant effort to routinely use collected clinical information to describe acute and chronic diseases to describe changes in the clinical condition of sensitive patients, such as cancer and infectious patients, whose delay or misdiagnosis leads to irreparable harm. The authors searched through all the notes between February 20 and March 31, 2020, to provide the dataset for this study by searching phrases such as: “coronavirus”, “Covid”, “sars-cov”, and “sars-2” to find Covid-19 related items. This study finds 92 K notes; 53 K are randomly selected, containing at least five phrases: telephone encounters, outpatient progress, emergency department, inpatient nursing, intensive care unit, and general inpatient medicine. They use logistic regression, SVM, decision trees, random forest, K-nearest neighbors (KNN), Naive Bayes, and multilayer perceptron to predict the disease, which RF has the best performance.

Khanday et al. [42] proposed integrating feature engineering and ML to detect Covid-19. In this manner, they selected 212 clinical reports written in English from an open-source data repository, GitHub, that included symptoms of Coronavirus or other viruses and labeled them into four classes: Covid, ARDS, SARS, and both (Covid and ARDS). Term frequency/inverse document frequency (TF/IDF), the bag of words (BOW), and report length extract forty related features. These features are then weighed and passed to several ML algorithms for classification. The authors evaluate the results of various ML algorithm analyses in two categories: traditional and classical, and four performance factors: accuracy, recall, and F1-score. Despite the small size of the used dataset, the evaluation results support that the study is comprehensive and accurate. Researchers should consider analyzing a more comprehensive database, separating patients based on gender, and applying ML classification and feature engineering to extract Covid-19 from clinical reports.

4.2.3 Audio-based detection of Covid-19

Covid-19 can be detected and predicted by analyzing medical images (CT scans, X-rays of the chest) and audio (cough, speech, and breathing samples) using several single-modal methods. Jayachitra et al. [43] proposed a multimodal model involving image and audio to increase the accuracy of coronavirus detection by 100%. Their approach included preparing several coronavirus infection symptoms and experimenting with different ML methods to develop a more accurate model for Covid-19. The collected sample data were organized into two categories, audio, and images, then trained using CovParaNet (an enhanced CNN model) and CovTinyNet models. Existing models are trained on the data, and finally, the two models mentioned earlier are selected as the most efficient. The team used MFCC to extract the features and DL to classify the audio samples, and ML to develop the best way to predict Covid-19. A final RF-based dynamic multimodal fusion model is evaluated by considering five classification criteria: accuracy, precision, recall, f-score, and ROC. A simultaneous assessment of four or more prediction methods found no case of misprediction. If the same situation recurs, the learned RF parameters will undergo retraining with dynamic retraining methods to ensure accuracy. Due to the lack of audio information, the model presented has a limited classification capability. In addition, it cannot differentiate Covid-19 from other lung diseases such as pneumonia, resulting in misdiagnosis. Other researchers may use this model to train other abnormalities of the lungs to distinguish them accurately and evaluate the same with a rich and expansive database.

4.2.4 IoT-based detection of Covid-19

Mohammedqasem et al. [44] proposed a real-time IoT-based system for diagnosing Covid-19 using AI-based classification algorithms. A combination of IoT datasets and laboratory data is used to train and prepare for the use of this system. Researchers encountered limitations due to the lack of large datasets for training in the detection of the outbreak. A pre-processing step is performed once sufficient datasets are prepared for system training; for example, existing datasets were unbalanced, so they used SMOTE to balance them. Additionally, they used feature selection to eliminate inefficient data, reduce training time, and make datasets more adequate by generating new data. The researchers then divided the final datasets into training and experimental categories. AI classifiers and learning algorithms used in the system trained them to detect Covid-19 cases and identify infected or potentially infected individuals based on their symptoms. Lastly, the authors evaluated this system against existing models, demonstrating its accuracy and reliability. Various feature selection techniques combined with larger imbalanced datasets can be employed to improve the detection accuracy of this system.

Pandemics must be predicted for prevention measures to be taken. There is a wide range of ML-based forecasting methods in the current critical situation, which could be helpful. However, finding the correct model to predict Coronavirus pattern spread in the absence of data is one of the main challenges Ketu & Mishra [45] face. They propose a multi-task Gaussian-process (MTGP) model and compare its performance with four traditional ML prediction models: linear regression, support vector regression, RF regression, and LSTM. In the process of comparison, they apply mathematical and statistical principles. The mean absolute percentage error (MAPE) and the RMSE are the criteria used to evaluate the performance of these five prediction models. These authors examine the performance of all models in four countries (China, India, Italy, and the USA) using these two evaluation criteria on different forecast days: one, three, five, ten, and fifteen days ahead. Results indicated that MTGP had the lowest MAPE and RMSE values, which means it was more effective than the other models tested. An essential challenge in this system is accurate and real-time data collection. IoT offers a practical solution by collecting data, tracking, and monitoring the infected people intelligently, along with the forecasting model. The lack of large datasets for intelligent analysis and characterization of virus behavior patterns is a significant problem in scientific research.

Sharma and Ahmed [46] proposed a Covid-19 prediction method based on a susceptible, exposed, infectious, recovered, undetectable, and deceased (SEIRUD) mathematical model as well as Markov decision process (MDP) and recurrent neural network (RNN) ML methods to forecast Coronavirus behavior among the population and the number of Covid-19 positive cases in Saudi Arabia. All methods for predicting, preventing, and detecting Covid-19 rely on data collected by IoT sensors and devices. The SEIRUD-MLA model employs big data gathered by IoT to evaluate and forecast the spread of Coronavirus across the country. As a result of these forecasts, the government decides to lock down only high-risk areas rather than the entire country. Thus, it reduces the disruption caused to the economy by Covid-19. The study's authors evaluate their proposed model using performance metrics such as F1 score, accuracy, prediction, precision, recall, and contact rate. Despite the result of the evaluations showing a high generalized forecasting rate in the long term, this model is based on data and behavior patterns for Coronavirus in Saudi Arabia and may have different results in other countries. The dataset may not be sufficiently accurate since this system receives data from IoT devices, whose use is optional. The proposed model could help countries with shortages of medical technology allocate resources efficiently.

Ahanger et al. [1] proposed a Covid-19 monitoring and forecasting framework that merges the IoT with spatial and temporal patterns through a model known as temporal recurrent neural networks (TRNN). TRNN is a DL technique that forecasts the likelihood of Covid-19 symptoms in geographical patterns. The architecture of this framework consists of four layers: The first level is Covid-19 data collection (C-19DC), which collects data from a variety of sensors and devices and sends it to a fog hub for analysis. Security, confidentiality, and integrity of information are data-related concerns addressed by the Secure Socket Layer (SSL) and Elliptic Curve Cryptography (ECC) over the HTTP protocol and the Message Queue Telemetry Protocol (MQTP). The second layer is the Covid-19 information classification (C-19IC), in which the data are classified into four categories based on their detail: Health data, Meteorological data, Location data, and Environmental data. The third layer is the Covid-19 mining and extraction (C-19ME) layer, between IoT devices and the remote cloud. A fog hub analyzes data and determines the state of health of individuals based on their computational capacity.

The fuzzy C-means (FCM) classifies data into non-infected and infected groups using a degree of membership (DOM) grade of 0 to 1. Covid-19 prediction and decision modeling (C-19PDM) is the fourth and final layer that predicts vulnerabilities utilizing the TRNN model for maximum accuracy. Fever measure (C-19FM) is a feature of this system that continuously monitors fever and other symptoms that can be taken to maximize healthcare in severe cases. In severe cases, the FCM classification assists healthcare organizations in detecting real-time hot spots that can be treated promptly by taking the appropriate precautions. A self-organization map (SOM) is a method for addressing the spatial–temporal dynamics of Covid-19 behavior. In this system, early detection of infection is detected, and a prompt message is sent to patients via their mobile devices, which results in crisis control. Researchers prepared regional datasets from India and categorized them into three categories. In the next phase, they test the effectiveness of their framework using sensors such as WiSense hubs, actuators, and RFID in each domain via the iFogSim simulator. Evaluation is performed based on efficiency metrics at the data generation, classification, and prediction stages. Optimum utilization of energy is recommended for the proposed framework.

4.2.5 Analysis of studies in the detection approaches

Table 8 summarizes the studies reviewed under the Covid-19 detection approaches. The main contexts of these papers, their advantages, weaknesses, evaluation parameters, applied solutions to tackle the challenges, and future work are briefly presented.

Considering that each paper uses some criteria to evaluate its method(s), we have listed and defined all the evaluation metrics used to analyze the detection approaches in Table 9. It demonstrates that most authors evaluated the Covid-19 detection approaches using metrics such as accuracy, f-measure, and recall.

4.3 Services provision

Nowadays, healthcare systems commonly use IoT with other technologies to partially compensate for its shortcomings. An increase in the number of intelligent devices, such as smartphones, home, and hospital equipment, and outdoor sensors, allows for the exchange of a large amount of data, which presents both threats and opportunities to healthcare. On the one hand, the availability of various applications allows for the provision of single and combined healthcare services to individuals, which represents a great opportunity if users' privacy through the blockchain is protected and the quality of services (QoS) is maintained. On the other hand, because IoT devices are small, their processing and storage capacity is limited, so cloud infrastructure, distributed systems, and FL methods are necessary to address this weakness. As a result, most storage and data processing occurs in smaller volumes within the edge and fog technologies and larger volumes within the cloud, significantly reducing delays and balancing network traffic. However, data exchange between users and cloud servers can present cost, infrastructure, privacy, and security challenges. The selection of composing services is challenging but can be improved when the QoS factors are considered [47]. Here, we review healthcare technologies, their challenges, and solutions presented by other researchers.

Hayyolalam et al. [48] proposed a framework for composing healthcare services that combine IoT, AI, cloud technologies, and edge intelligence. In this study, the Edge Device as a Service (EDaaS) concept allows healthcare applications and services to be more intelligent by incorporating AI algorithms into resource-limited edge devices. They design a framework for composing AI subtasks that can be considered reliable in terms of QoS and quality of experience (QoE). By employing the proposed framework, when a user submits a single or combined request to a healthcare application, rather than a single device completing the entire task, it is divided into multiple subtasks assigned to different edge devices. All subtasks are compiled and distributed to the user without being aware that they are divided. Because of the many devices and solutions, distributing IoT data and AI subtasks becomes NP-Hard. Therefore, the authors applied three meta-heuristic algorithms (PSO: particle swarm optimization, BWO: black widow optimization, simulated annealing) to identify uncertain and near-optimal edge devices. They assessed the framework's efficiency utilizing these three algorithms using MATLAB simulation in healthcare applications and discovered that BWO was more efficient than PSO or simulated annealing. The framework's scalability, fitness, availability, reliability, and QoS were evaluated. This study assumed that all edge devices and users were part of the same network, and the network size was determined solely by the number of devices connected to it. There is the possibility that future researchers may move edge devices to a different network to compose services. In addition, the impact of the proposed method on the performance of AI algorithms may be explored in the future.

Asghari et al. [49] proposed a framework based on IoT data (IoTD) and cloud technologies. Patients' physical symptoms are collected through the body and environmental sensors and incorporated into their medical history in cloud repositories. The patient's whole health data would be analyzed to provide a composite health/medical prescription, and the results reported by medical teams would be shared with the patients. Following the appropriate treatment instructions for the patient's condition, they can select their preferred services. Although the same services are available at different centers, the locations, times, and costs may differ. In this manner, patients or their relatives can choose the services and features they desire, and the system will determine the most appropriate combination for them. The authors applied data collected from diabetic patients in medical centers to evaluate the effectiveness of their proposed framework; they also developed simulating techniques to evaluate IoT data. The final step of their study was to test several classification algorithms to diagnose the disease and determine accuracy, precision, recall, and F-score. In comparing several classification algorithms, K-Star is more effective than others. The accuracy metric could be compared in future research to the usual methods used by physicians. Additionally, they suggested integrating data mining methods and meta-heuristic approaches with the proposed framework and subsequently implementing them in practice.

Secundo et al. [50] proposed a framework based on collective intelligence for combating Covid-19 utilizing IoT technologies in combination with other digital technologies. The authors propose reforming the healthcare system to improve the management of this pandemic in Italy and optimize the distribution of devices and services based on IoT among patients affected by Coronavirus. This article aims to establish proper coordination among different institutions to harness IoT devices to take appropriate action. They select and apply several indicators to the weighting of severe diseases based on survey data and analysis of their study data. An evaluation was conducted on seven patients, three devices, and two criteria of acuity and efficiency. An assessment based on a data set is not valid, and as a result, the results are not reliable. More accurate statistical evaluation at an acceptable scale makes it possible to complete a more comprehensive strategy development and implementation study.

During an epidemic, receiving and processing people's health data is very important to identify and service the affected. Çalhan and Cicioğlu [51] proposed a framework based on drones and sensors in which data are collected by ground sensors and sent to drones covering the same area. Drones categorize data considering its importance and send the highest priority to the central point for processing. The AODV routing algorithm routes the drones and their

Table 8 The classification of studies in the detection approach

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Nasser et al. [35]	Intelligent detection system combining IoT, cloud, and DL methods	Improving the quality of life Lowering costs Enhancing reliability Increasing the quality and speed of medical devices	Using CT scans in place of X-rays Using cloud technology instead of fog Labeling research datasets by radiologists manually instead of by using automatic classification methods	Accuracy Sensitivity Specificity F-measure	Dataset (Covid-Chestxray and Chex-Pert datasets)	An intelligent detection system that aids professionals in detecting diseases using DL techniques	Applying more sophisticated DL techniques Expanding the datasets and utilizing X-ray images instead of CT scans Using multiple classes to improve diagnosis accuracy Implementing the proposed model within the healthcare system
Laxmi Lydia et al. [36]	Proposing a federated DL-based model using mobile edge technology equipped with IoT to diagnose Covid-19	Enhancing privacy Resolving dataset deficiencies Speeding up the detection of Covid-19 Reducing latency through edge computing Lowering costs	Not taking into consideration the training capabilities of edge devices, data standardization, and model convergence for FL-based techniques	Sensitivity Specificity Accuracy	Dataset (Chest X-Ray images) Simulation	Integrating data from distributed datasets and preserving privacy through federated DL-based models	Data offloading Resource management Enhancing the (MEC) platform
Pereira et al. [37]	Presenting a classification model of pneumonia caused by different pathogens from chest X-ray images for diagnosis of Covid-19	Reducing costs Speeding up Covid-19 detection Enhancing the accuracy of Covid-19 detection	Not using comprehensive datasets Not utilizing sophisticated DL techniques Analysis based on only one criterion	F-measure	Dataset (Chest X-ray14))	Classifying the inflammations on CXR images of Covid-19 pneumonia based on both flat and hierarchical classification Resampling technique to address the imbalance of pneumonia types in CXRs	Expanding the datasets Cross-validating Applying more sophisticated DL methods Extracting additional features Classifying locally

Table 8 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Le et al. [38]	Proposing an improved CNN to classify X-ray images and diagnose Covid-19	Increasing detection accuracy Accelerating diagnosis of Covid-19 Minimizing human intervention	Not hyper parameterized	Sensitivity Specificity Accuracy F-measure	Dataset (Chest X-Ray images) Simulation (Python) Implementation	Maximizing classification performance by using the DSVM	Adapting DWS-CNN hyperparameters Utilizing bio algorithms
Ahmed et al. [39]	Proposing a framework to detect and predict Covid-19 infection based on big data analysis and ML mechanisms	Analyzing the real pandemic data Reducing the workload of treatment staff Improved diagnostic accuracy Speeding up the decision-making	Not addressing potential security threats	Accuracy Precision Recall F-measure	Dataset (collected from different hospitals in Khyber-Pakhtunkhwa, Pakistan)	Applying NN methods to describe, diagnose, predict, and ultimately prescribe solutions to Covid-19	Providing security, privacy, and integrity of this study
López-Úbeda et al. [40]	Proposing a method for automatic detection of Covid-19 from chest CT images using feature extraction and text classification	Enhancing diagnosis of unexpected diseases Accelerating the detection of Covid-19 Increasing patient notifications	Not a comprehensive analysis of the model	Precision Recall Accuracy F-measure Matthews Correlation Coefficient (MCC) ROC	Dataset (Radiological reports)	Processing radiological reports using NLP, ML, and DL through feature selection, classification, and automatic detection	Analyzing in-depth Utilizing different classification models Evaluating richer databases Enhancing detection accuracy Shortening clinical documents
Lybarger et al. [41]	Introducing a new framework for the extraction of neural events from clinical text to diagnose Covid-19	Increasing diagnosis efficiency	There are only limited notes in the dataset of this study (February to March)	Precision Recall F-measure ROC	Dataset (The University of Washington clinical repository contains inpatient and outpatient clinical notes)	Analyzing clinical notes using a neural event extraction model to diagnose and predict Covid-19	Prioritizing experiments Improving the model on a larger scale Adding the ability to diagnose various diseases Accelerating the detection of acute illnesses

Table 8 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Khanday et al. [42]	Covid-19 identification from clinical records using ML algorithms and feature engineering	Enhancing detection accuracy Accelerating detection Reducing treatment staff involvement	Not comprehensive datasets	Recall F-measure Accuracy	Dataset (collected clinical notes) Implementation	Using feature engineering and ML algorithms to detect Covid-19 in clinical reports	Using NN Improving accuracy
Jayachitra et al. [43]	Proposing multiple modality classifiers to improve the detection and prediction of Covid-19	Online retraining Accuracy Reliability Minimizing computational complexity Speeding up the training process	Not comprehensive datasets, especially audio Inability to distinguish Covid-19 from other lung disorders	Accuracy Precision Recall F-measure ROC	Dataset (Two different datasets) Implementation (in google colab workspace)	Combining several single-modality classification models to develop an accurate multiple-modality model for Covid-19	Improving diagnosis accuracy Training various pulmonary abnormalities to distinguish Covid-19 from other disorders Enriching evaluation datasets
Mohammedqasem et al. [44]	Covid-19 real-time detection system based on IoT and AI	Working with imbalanced datasets Scalability Compatibility	Not sufficient and balanced datasets	Accuracy Precision F-measure Recall ROC	-Datasets (Laboratory data)	Using SMOTE and feature selection to reduce training time and balance laboratories datasets for Covid-19 detection	Improving prediction accuracy Applying various feature selection and learning algorithms Enriching datasets
Ketu & Mishra [45]	Predicting Coronavirus outbreaks using IoT based on the multi-task Gaussian process regression model	Enhancing predictions of Covid-19 Improving prevention planning in countries Mitigating the adverse effects of the pandemic	-Not re-analyzing the model with variant datasets	Mean Absolute Percentage Error (MAPE) RMSE	Dataset (World Health Organization) Implementation	Gathering real-time data by IoT and predicting the expansion model of Covid-19 by MTGP to take prompt action	Enriching datasets Improving efficiency Utilizing the Sparse Gaussian Process

Table 8 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ Implementation/ Dataset	Solution	Future work
Sharma & Ahmed [46]	Proposing a Covid-19 prediction method using the SEIRUD mathematical model, MDP, and RNN	Increasing generalizability Minimizing infection Reducing the extent of lockdown areas Improving the country's economy	Providing a forecast model based only on the circumstances of Saudi Arabia and not the of other countries	Accuracy Prediction Precision Recall F-measure Contact rate	Dataset (Saudi Arabian real-time IoT data) Implementation	Estimating the number of Covid-19-infected individuals in different geographical regions	Implementing the model in countries with a shortage of medical technology
Ahanger et al. [1]	Proposing a Covid-19 prediction framework based on network-layered architecture and AI	Reducing latency Decreasing network traffic Improving load-balancing	Perception loss by sensors due to the incompatibility of IoT devices	Accuracy Precision Recall F-measure Reliability Time	Dataset (Three regional datasets from Amritsar, India) Simulation (iFogSim/ MATLAB)	Collecting data through IoT, classifying data using AI, maintaining data with security protocols, and predicting Covid-19 through the application of DL	Enhancing the energy-productivity of C-19VI arrangements

communication with sensors. They evaluated their proposed framework's performance in Riverbed Modeler simulation based on throughput, delay, and energy consumption. Also, they compared the simulated scenario with the traditional one without fog computing. The results show the capability of this framework in real-time IoT-based applications. The proposed framework is computationally complex, and the decision speed of drones is low, which can be improved to be used in denser networks. The design can also be upgraded to an integrated network architecture with cloud computing and evaluated in various simulators.

A significant application of computer science in medicine is the design of robots that simulate medical procedures. The therapy staff typically performs coronavirus testing by sampling the throat, which may increase the likelihood of infections. Chen et al. [52] designed a novel flexible robot that automatically and remotely performs oropharyngeal swabbings gently and accurately. As part of the throat, the oropharynx lies between the soft palate and the hyoid bone and is very sensitive and vulnerable. Therefore, designing a robot for intelligent sampling, predicting the vulnerabilities of this area, the patient's unconscious reactions, and the robot's flexibility for medical safety. The authors designed flexible and intelligent robots specialized in localization and visual recognition in this study and then, evaluated their efficiency in five dimensions: efficiency, quality, experience, safety, and adaptability. The results prove that their robot was more efficient than other rigid robots.

Service-oriented architectures use cloud-based services and distribute them across IoT devices flexibly, helping to minimize costs and increase availability [53]. In this process, the selection of service providers and edge devices is an NP-Hard problem, and the optimal selection determines the QoS delivery, achieved using meta-heuristic algorithms. Accordingly, researchers have conducted numerous experiments involving different algorithms that have been subjected to similar performance evaluations and comparisons. Wang and Lu [53] developed a model based on a multiobjective meta-heuristic algorithm to improve the selection of cloud services. The authors combined Grey Wolf Optimizer with a Genetic Algorithm (GWO-GA) and evaluated the performance using several QoS metrics using the MATLAB programming language. As a result of these tests, the GWO-GA performed 30% better than other models in cost, energy consumption, and time.

Guzel and Ozdemir [54] proposed a framework for composing IoT services based on the NSGA-II multi-objective meta-heuristic algorithm to optimize energy efficiency and fairness without compromising QoS in a cloud and fog environment. They divide requests into repetitive IoT devices while maintaining QoS. They used the Python

Table 9 Comparison of factors involved in the detection approaches

Research	Accuracy	Sensitivity	Specificity	F-measure	Precision	Recall	MCC	ROC	MAPE	Contact rate	Reliability	RMSE
Nasser et al. [35]	✓	✓	✓	✓	×	×	×	×	×	×	×	×
Laxmi Lydia et al. [36]	✓	✓	✓	×	×	×	×	×	×	×	×	×
Pereira et al. [37]	×	×	×	✓	×	×	×	×	×	×	×	×
Le et al. [38]	✓	✓	✓	✓	×	×	×	×	×	×	×	×
Ahmed et al. [39]	✓	×	×	✓	✓	✓	×	×	×	×	×	×
López-Úbeda et al. [40]	✓	×	×	✓	✓	✓	✓	✓	×	×	×	×
Lybarger et al. [41]	×	×	×	✓	✓	✓	×	✓	×	×	×	×
Khanday et al. [42]	✓	×	×	✓	×	✓	×	×	×	×	×	×
Jayachitra et al. [43]	✓	×	×	✓	✓	✓	×	✓	×	×	×	×
Mohammedqasem et al. [44]	✓	×	×	✓	✓	✓	×	✓	×	×	×	×
Ketu & Mishra [45]	×	×	×	×	×	×	×	×	✓	×	×	✓
Sharma & Ahmed [46]	✓	×	×	✓	✓	✓	×	×	×	✓	×	×
Ahanger et al. [1]	✓	×	×	✓	✓	✓	×	×	×	×	✓	×
Total	10	3	3	11	7	8	1	4	1	1	1	1

programming language to evaluate the efficiency of their framework in the presence of different sizes of networks, and the results show superiority. This study is limited by its scalability, which may be addressed later.

IoT devices provide different levels of quality for the same services, which has made QoS a significant benchmark of service computing optimization due to the overwhelming number of IoT devices currently available. Thus, Boucetti et al. [55] proposed a method for large-scale optimization of service computing based on NN clustering after applying GA to reduce the search space and execution time while maintaining QoS. Simulations demonstrate that the optimization, time, and hyper-volume indicators are more reliable and dynamic. DL methods for predicting service computing more accurately could be beneficial for improving the effectiveness of the proposed framework. Implementation in a real-world environment is also one of the study's limitations.

Souri and Ghobaei-Arani [56] proposed an approach that combines cloud services with the Whale Optimization Algorithm (WOA) to maintain QoS in IoT-based applications. To evaluate the different Linear Labeled Temporal Logic (LTL) properties and various cloud providers, they used Labeled Transition System (LTS) as a formal verification method. Although they do not consider the challenges associated with web-based services, the Process Analysis Toolkit (PAT) simulation is highly efficient in reachability, time, and memory consumption.

Arunachalam and Amuthan [57] proposed a way to optimize the composition of web-based services that utilizes graph-based workflow diagrams and Bee colony optimization algorithms to arrive at the most optimal solution. The authors of this study used multiple search rules and meta-heuristic algorithms to reduce the complexity of the service integration process and enhance QoS. The proposed approach is implemented using Java programming language, and various indices such as response time, accuracy, recall, precision, success rate, and optimality are evaluated.

Rahman et al. [58] provided an intelligent system for diagnosing and monitoring critical cardiac arrhythmia COVID-19 patients with COVID-19 based on fuzzy logic and IoT. Through pre-processed ECG signals, this system provides services to patients in remote areas. MIT-BIH ECG data are used to train the program, and evaluation proves it to be 100 percent accurate.

Considering that contact with contaminated surfaces is a major method of transmission, Iadanza et al. [59] developed a smart system that combines a robotic arm and a mobile application to limit direct contact between persons infected with Coronavirus and people and medical equipment in hospitals and health facilities. This system is microcontroller-based and operates at a reasonable speed

Table 10 The classification of studies in the service provision approach

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ implementation/dataset	Solution	Future work
Hayyolalam et al. [48]	Framework based on multiple AI sub-services for integrated services	Dynamicity Applicability Reliability Fault tolerance Reducing latency Network balancing	Consideration of all edge devices and users within a network Constant number of AI sub-tasks Changing the number of edge devices to modify network size	Scalability Fault tolerance Success rate Similarity Time	Simulation (MATLAB)	Subdividing the AI task to overcome limited storage and computation capacity	Considering edge devices and requesters in different networks in the process of SC
Asghari et al. [49]	Service computing monitoring for disease prediction using IoT and cloud	Privacy Security Speeding up the diagnosis	Not real-world implementation Not using meta-heuristic algorithms	Accuracy Precision Recall F-measure	Dataset (Diabetes and health data)	Diagnosing diseases using IoT in the cloud using classification algorithms	Applying meta-heuristic algorithms to data mining Implementing in a real-world
Secundo et al. [50]	Medical device distribution to Covid-19 patients based on collective intelligence	Increasing the return on investment Improving the distribution of medical devices	Insufficient dataset Lack of technical review	Acuity Efficiency	Dataset (prepared by the authors)	Using collective intelligence for IoT devices distribution among patients	Enriching dataset Evaluating this model in different countries
Çalhan and Cicioğlu [51]	A fog-based data collection framework to provide services using drones	Reducing the workload of networks Enhancing network balancing	Computational complexity	Throughput Time Energy	Simulation (Riverbed Modeler)	Using multiple drones to serve different areas	Reducing computational complexity Using the integrated cloud to serve denser areas
Chen et al. [52]	Designing a flexible robot to perform swabbing	Flexibility Increasing safety Mitigating risk	No real-time positioning and recognition	Safety Adaptation Efficiency Quality	Simulation (robot)	Swabbing with a flexible robot to prevent Coronavirus	Using force-sensing and multi-dimensional force control systems

Table 10 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ implementation/dataset	Solution	Future work
Wang and Lu [53]	Service discovery model using meta-heuristic algorithms	Reducing cost Lowering energy consumption Optimizing service discovery	Not dynamic	Time Energy Cost	Simulation (MATLAB) Dataset	Using GWO and GA for efficient service discovery	Dynamic Service discovery Privacy Security
Guzel and Ozdemir [54]	Meta-heuristic algorithm for composing IoT services	Efficiency QoS	Not scalable	Fairness Energy Quality	Simulation (Python)	Optimizing the trade-off between energy and fairness using meta-heuristic algorithms	Scalability Reducing processing time
Boucetti et al. [55]	IoT service computing optimization using GA and NN	Reliability Dynamicity QoS Minimizing search space Reducing time	No consideration of trust, privacy, and mobility Not real-world implementation	Time Optimality Hyper-volume indicators	Simulation	Optimizing service computing by integrating GA and NN, reducing search space and execution time	Using DL to predict services -Improving efficiency Implementing a real-world platform
Souri and Ghobaei-Arani [56]	An approach to composing cloud services for IoT	Lack of deadlock Reachability Analyzing a variety of cloud providers	Not consideration of web services	Reachability Verification time Deadlock Memory usage	Simulation (PAT)	Using WOA to maintain QoS as cloud services expand	Study on web-based services
Arunachalam and Amuthan [57]		Reducing complexity		Response time Accuracy Recall Precision Success rate Optimality	Implementation (Java)		Reducing complexity in finding optimal path based on graph

Table 10 (continued)

Research	Main context	Advantage	Weakness	Evaluation parameters	Simulation/ implementation/dataset	Solution	Future work
Rahman et al. [58]	An intelligent system for diagnosing and monitoring critical cardiac arrhythmias in COVID-19 patients using fuzzy logic and IoT	-Accuracy -Real-time -Simple calculation Needing short time and few resources -Low-cost	Depending on a pre-existing network infrastructure at the patient's location	Accuracy Recall Precision Cost Energy	Implementation (MATLAB) Dataset (MIT-BIH[1])	Analysis of real-time ECG data using IoT technology and fuzzy logic to improve cardiac patients with COVID-19 diagnosis and monitoring	Using the proposed system in the real world
Iadanza et al. [59]	Developing an automatic robotic system to control the spread of Coronavirus by reducing contact between people and medical equipment	Efficiency Quickness	Not testing in the real environment alongside a medical device	Severity Risk	Implementation (UML, CAD, SolidWorks) Simulation (Ionic 5Angular- Capacitor)	Making a robotic arm to reduce direct contact to prevent Coronavirus transmission	Combining the proposed system with medical devices Considering more standard rules
Munawar et al. [60]	Drone-as-a-service for delivering healthcare kits to remote areas affected by the COVID-19 pandemic	Environmentally friendly	Not comparing the ABC algorithm with other optimization algorithms suitable for the discrete space of the problem	Time Cost	Implementation (Python)	Providing health essentials in remote areas at an optimal cost and speed by applying the ABC algorithm	Using smokeless vehicles for delivery Implementation in multiple countries

[1] https://physionet.org/content/mitdb/1.0.0/

Table 11 Comparison of factors involved in the service provision approaches

Research	Scalability	Accuracy	Precision	Recall	F-measure	Throughput	Energy	Cost	Safety	Fairness	Time	Severity	Risk
Hayyolalam et al. [48]	✔	×	×	×	×	×	×	×	×	×	×	×	×
Asghari et al. [49]	×	✔	✔	✔	✔	×	×	×	×	×	×	×	×
Secundo et al. [50]	×	×	×	×	×	×	×	×	×	×	×	×	×
Çalhan and Cicioğlu [51]	×	×	×	×	×	✔	✔	×	×	×	×	×	×
Chen et al. [52]	×	×	×	×	×	×	×	×	✔	×	×	×	×
Wang and Lu [53]	×	×	×	×	×	×	✔	✔	×	×	×	×	×
Guzel and Ozdemir [54]	×	×	×	×	×	×	✔	×	×	✔	×	×	×
Boucetti et al. [55]	×	×	×	×	×	×	×	×	×	×	×	×	×
Souri and Ghobaei-Arani [56]	×	×	×	×	×	×	×	×	×	×	×	×	×
Arunachalam and Amuthan [57]	×	✔	✔	✔	×	×	×	×	×	×	×	×	×
Rahman et al. [58]	×	✔	✔	✔	×	×	✔	✔	×	×	×	×	×
Iadanza et al. [59]	×	×	×	×	×	×	×	×	×	×	×	✔	✔
Munawar et al. [60]	×	×	×	×	×	×	×	✔	×	×	✔	×	×
Total	1	3	3	3	1	1	4	3	1	1	1	1	1

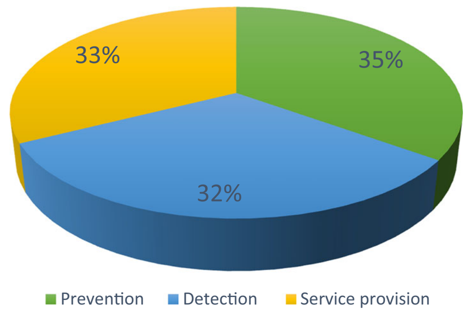

Fig. 5 Computer-aided methods for combating Covid-19 in prevention, detection, and service provision approaches

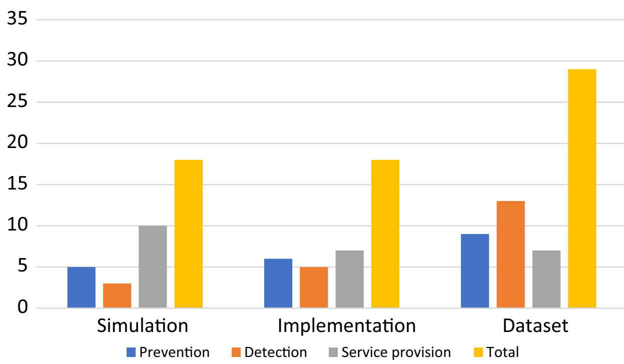

Fig. 6 Evaluation environments used in the computer-aided methods

and with high accuracy. Although this design has not been tested in a real-world environment with medical equipment, preliminary risk assessments demonstrated its efficiency and effectiveness. Angular, Ionic 5, Capacitor, UML, CAD, and SolidWorks are used to design this system, and this proposed plan be tested in the real world by considering more rules and standards as they relate to healthcare devices as a direction for future research.

It is possible to provide people with healthcare supplies, medicine, self-test kits, and their delivery during the Covid-19 pandemic. Munawar et al. [60] suggested systems for delivering healthcare packages by drone in Australia that use the ABC algorithm to improve time and cost efficiency while minimizing environmental impact. They implemented their design in Python programming language and evaluated the results in terms of fitness, time, and cost. The study has the limitation of not comparing the performance of the proposed algorithm with other discrete space optimization algorithms, like the Imperialist Competitive Algorithm (ICA). In the future, this study could be implemented in other countries with smokeless vehicles to reduce the environmental impact.

4.3.1 Analysis of studies in the service provision approaches

Table 10 summarizes the studies reviewed under the Covid-19 service provision method. The main contexts of these papers, their strengths, weaknesses, evaluation approaches, applied solutions to tackle the challenges, and future work are briefly presented.

Considering that each paper uses some criteria to evaluate its method(s), we have listed and defined all the evaluation metrics used to analyze the service provision approaches in Table 11. It demonstrates that most authors evaluated the Covid-19 service provision approaches using the throughput metric.

5 Discussion

This section will answer the research questions that are the primary purpose of this study according to the technical analysis done in the previous section. Some questions are statistical, so we answer them graphically to facilitate readers' understanding. Others need a detailed explanation, which we have a separate section to answer.

- *AQ 1* Which domains are involved in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?

According to the taxonomy proposed in Sect. 4, Figure 5 compares the number of studies conducted in the three approaches: prevention, detection, and service provision. The prevention approaches have the highest percentage of the domains, with 35% usage in the literature.

- *AQ 2* What are the evaluation environments and datasets used in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?

Figure 6 depicts the evaluation environments for Covid-19 prevention, detection, and service provision the computer-aided methods. This figure demonstrates that most methods utilized datasets to evaluate the concept presented in the paper.

Table 12 lists the majorly used datasets for Covid-19 prevention, detection, and service provision. It displays the proposed classifier(s) along with their respective advantages that were used for Covid-19, as well as the higher accuracy rate that can be attained by the best classifier of each paper. As demonstrated in this table, there are a variety of datasets with varying classification purposes and classifiers. Therefore, comparing papers and selecting the most effective classifier is impossible. In general, the most effective methods/classifiers are the ResNet50 CNN,

Table 12 Dataset specifications of used computer-aided methods and their advantages and accuracy rate in this study

Research	Dataset	Used methods (classifier)	Advantage	% Accuracy rate
Ahanger et al. [1]	Collected real datasets by authors from Amritsar, India Regional IDs	Fuzzy C-means	Better accuracy rate, precision, recall, and f-measure compared with Fuzzy KNN, Random decision tree, Naive Bayes algorithms	94.9
Barnawi et al. [2]	FaceScrub and VGGFace2, VGG16, VGG19, MobileNet, DenseNet121, ResNet50, InceptionV3 and InceptionResNetv2	SVM, XGBoost, KNN, multi-layered perceptron, logistic regression	Presenting a face recognition system to detect people having high body temperature and presenting a face mask detection	-
Castiglione et al. [3]	Covid-19 Symptoms Checker https://www.kaggle.com/iamhungundji/Covid19-symptoms-checker	Gradient boosting, extra tree classifier, random forest, AdaBoost, voting classifier, logistic regression plus stochastic gradient descent	Real-world implementation and comparing the performance of five machine learning classifiers	75.4 for the best classifier, random forest
Garg et al. [20]	Call Detail Record (CDR) Analysis: Sierra Leone https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Documents/2017/Reports/ SL/D012A0000CA3301PDFE.pdf	Not using any classifier	–	–
Bhatia et al. [22]	A synthetic dataset is created	J48 decision tree-based classifier	Better accuracy rate, sensitivity, and f-measure compared with Random tree, REP tree, and Naive Bayes algorithms	96.78
Wu et al. [23]	Two public datasets included images of different faces with and without masks https://www.kaggle.com/andrewmvd/face-mask-detection https://aistudio.baidu.com/aistudio/datasetdetail/24982	YOLO algorithm based on CNNs	Presenting a face mask detection	The average precision is 92.0
Otoom et al. [24]	Covid-19 Open Research Dataset (CORD-19) https://zenodo.org/record/3715506	SVM, Naive Bayes, NN, decision stump, KNN, decision table, OneR, and ZeroR	Comparing the performance of eight machine learning classifiers	92.95 for the best classifier, SVM
Nasser et al. [35]	Covid-Chestxray dataset and Chex-Pert dataset)	ResNet50 CNN	Using the ResNet50a classification algorithm based on DL	98.6
Laxmi Lydia et al. [36]	Covidx dataset: Chest X-Ray images	Presenting a federated DL-based Covid-19 detection model	Better accuracy compared to the other four algorithms: Fed. Learning-VGG16, Cen-VGG16, Fed. Learning-ResNet50, Cen.-ResNet50	97
Pereira et al. [37]	NIH dataset (Chest X-ray14)	Macro average evaluation: a class-based mean calculation	Classifying the inflammations on CXR images of Covid-19 pneumonia based on both flat and hierarchical classification	–

Table 12 (continued)

Research	Dataset	Used methods (classifier)	Advantage	% Accuracy rate
Le et al. [38]	Chest X-Ray (CXR) images https://github.com/ieee8023/Covid-chestxray-dataset	Depthwise separable convolution neural network with DSVM	Maximizing classification performance by using the DSVM	98.54 for binary and 99.06 for multiclass
Ahmed et al. [39]	Collected from different hospitals in Khyber-Pakhtunkhwa, Pakistan	Adaboost, SVM, KNN, logistic regression, Naive Bayes, neural network	Providing security, privacy, and integrity	99 for the best classifier, neural network
López-Úbeda et al. [40]	Collected radiological reports from 295 chest CTs provided by the "HT médica" clinics	SVM for predicting lung infection by Covid-19	Processing radiological reports using NLP, ML, and DL through feature selection, classification, and automatic detection	85
Lybarger et al. [41]	Covid-19 Annotated Clinical Text (CACT) Corpus: The University of Washington clinical repository	Span-based Event Extractor	Diagnosing Covid-19 by analyzing clinical notes using a neural event extraction model	Precision is 94
Khanday et al. [42]	Collected clinical notes, also from the following website: https://github.com/Akibkhanday/Meta-data-of-Coronavirus	Logistic regression, multinomial Naive Bayes, decision tree, bagging, Adaboost, random forest, SVM, stochastic gradient boosting	Detecting Covid-19 in clinical reports by using feature engineering and ML algorithms	96.2 for the best classifiers, logistic regression and multinomial Naive Bayes
Jayachitra et al. [43]	Two different datasets Virufy Covid-19 Open Cough Dataset: https://github.com/virufy/virufy-data Coswara-Data: https://github.com/iiscleap/Coswara-Data	CovParaNet, CovTinyNet CNN, RNN	Presenting two models, CovParaNet for audio (cough, speech, breathing) and CovTinyNet for images (X-rays, CT scans)	97.12 for cough 96.08 for speech, 97.45 for breathing, for the best classifier, CovParaNet 98.40 for Chest X-ray, 99.19 for Chest CT, for the best classifier, CovTinyNet
Mohammedqasem et al. [44]	Collected laboratory results from Albert Einstein Hospital located in Brazil	Artificial neural network	Balancing laboratories datasets for Covid-19 detection	98
Ketu & Mishra [45]	World Health Organization situation reports	Multi-Task Gaussian Process Regression	Gathering real-time data by IoT and predicting Covid-19 outbreaks using an IoT-based model	–
Sharma & Ahmed [46]	Collected from Saudi Arabian real-time IoT data	Susceptible, Exposed, Infectious, Recovered, Undetectable, and Deceased, and ML algorithm	Estimating the number of Covid-19-infected individuals in different geographical regions	89.3
Asghari et al. [49]	Diabetes and health data	K-Star, random forest, SVM, multilayer perceptron and J48	Diagnosing diseases using IoT in cloud computing and comparing the performance of five machine learning classifiers	98, for the best classifier, K-star
Secundo et al. [50]	Prepared by the authors	Medical device distribution to Covid-19 patients based on collective intelligence	Using collective intelligence for IoT devices distribution among patients	–
Wang and Lu [53]	QWS dataset	Service discovery model using meta-heuristic algorithms	Using GWO and GA for efficient service discovery	–

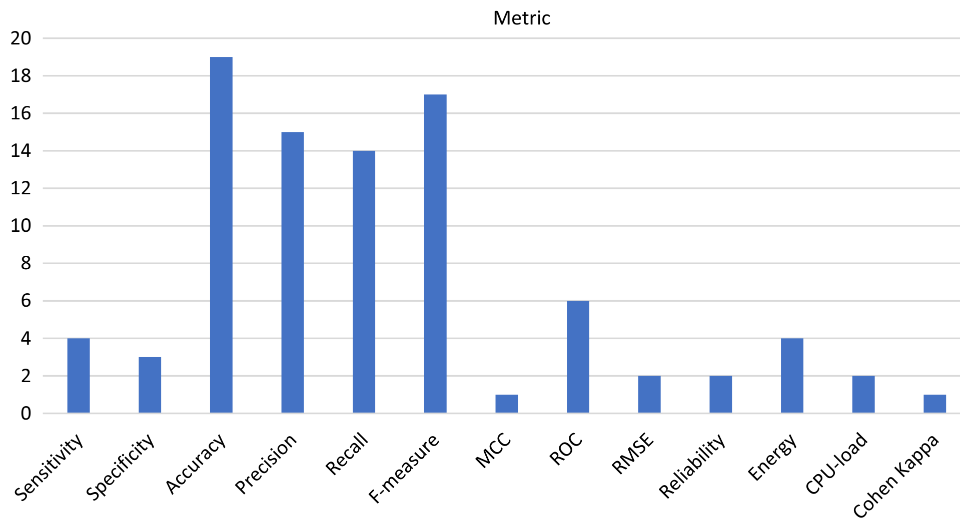

Fig. 7 Evaluation metrics used in all approaches

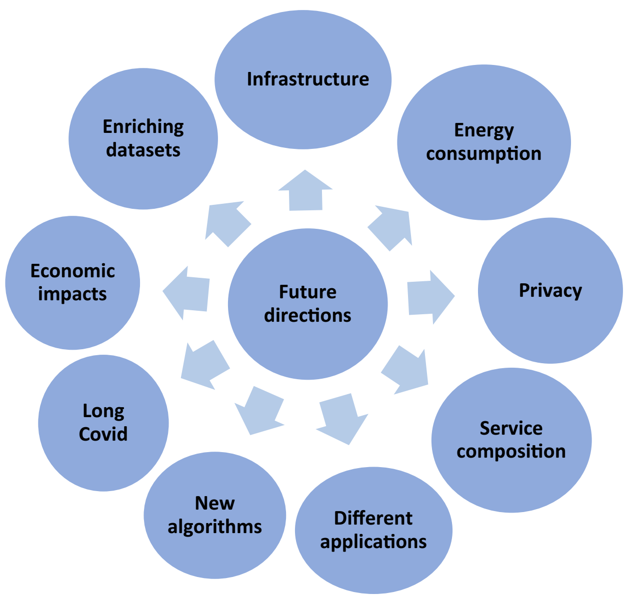

Fig. 8 Future directions of computer-aided methods for combating Covid-19

Depthwise separable convolution neural network with DSVM, CovParaNet, CovTinyNet CNN, and K-star.

- *AQ 3* Which evaluation metrics are used in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?

We analyzed several computer-aided methods to combat Covid-19 detection, prevention, and service provisioning based on their metrics. However, certain metrics are so important that they are considered in every approach. Therefore, we compared every metric used to identify the most important metrics in this field. The six significant evaluation metrics for computer-aided methods in real-world applications of Covid-19 are defined by Eqs. (1) through (6) [49].

$$\text{Sensitivity} = \text{TP}/(\text{TP} + \text{FN}) \quad (1)$$

$$\text{Sensitivity} = \text{TN}/(\text{TN} + \text{FP}) \quad (2)$$

$$\text{Accuracy} = (\text{TP} + \text{TN})/(\text{TP} + \text{FP} + \text{FN} + \text{TN}) \quad (3)$$

$$\text{Precision} = \text{TP}/(\text{TP} + \text{FP}) \quad (4)$$

$$\text{Recall} = \text{TP}/\text{TP} + \text{FN} \quad (5)$$

$$F - \text{measure} = 2x\left[(\text{Precision}\ x\text{Recall}) / (\text{Precision} + \text{Recall})\right] \quad (6)$$

where True positive (TP) is a situation in which both predicted and observed values are positive. True negative (TN) is a situation in which both predicted and observed values are negative. False positive (FP) is a situation in which the predicted value is positive, but the observed value is negative. False negative (FN) is a situation in which the predicted value is negative, but the observed value is positive.

Figure 7 shows the evaluation metrics used in each of the Covid-19 domains discussed in this study. Accuracy and f-measure have the highest repetition rate, indicating that they are the most important metrics for computer-aided methods.

5.1 Open issues and future directions

In this paper, SLR has helped clarify all the open issues raised by other researchers but has not been addressed until now. In response to AQ 4, we identified challenges in the studies reviewed and proposed them as directions for the future.

- *AQ 4* What future research directions should be pursued in computer-aided methods for combating Covid-19 in prevention, detection, and service provision?

Figure 8 shows open issues and future directions of computer-aided methods for combating Covid-19. These future directions were discussed as follows:

Infrastructure Healthcare systems today rely on IoT, which has been applied on a massive scale at both the personal and the urban levels. The production of vast amounts of information using these devices over a wide geographical area necessitates infrastructure to accommodate that volume of information. The integration of those devices results in improved processing speed and privacy at a reduced cost. Cloud and fog infrastructure are necessary to meet these needs, but this technology has several challenges that could be considered an open topic [61].

Energy consumption All Covid-19 approaches collect health data from various distributed devices and centers, presenting distinct challenges in energy consumption, battery life, and network load balance relative to centralized systems. This problem is caused by the need to transfer data to a remote data center. Consequently, this issue can be used as a basis for future studies [62].

Privacy There are several challenges associated with privacy in intelligent healthcare systems. First, tracking applications are voluntary, and people are not willing to use this technology until they trust it. Secondly, every stage of collecting personal health information, the transfer to powerful servers for storage and processing, and the disclosure of results of analyses, including medical, statistical, or spatial analyses, conforms to privacy principles. Thus, information security, confidentiality, data integrity, and cyberattacks can be widely discussed [63].

Service composition IoT is a network of interconnected intelligent devices that provide various services [64]. IoT-derived services can also play a vital role in combating the Covid-19 epidemic by using meta-heuristic algorithms to select and combine them optimally. Considering the contagious nature of this disease, remote, emergency, and fast services can be essential in reducing mortality and the spreading of the disease. We plan to devote a separate article to this topic because the research in this field is so extensive.

Enriching datasets The lack of validated datasets of real-world patients poses one of the challenges of studying Covid-19. Due to privacy concerns, medical centers, doctors, and even patients are reluctant to report health information. Thus, this information needs to be collected from distribution centers and points using technologies such as FL, integrated, and then distributed among the nodes of the health network. In future studies, it may be beneficial to examine the methods of enriching real datasets of patients' health status and the impact of disease on their long-term health [65].

Different applications In the future, we can use computer-aided programs for various purposes, such as presenting applications to evaluate the effectiveness of the Covid-19 vaccine. It is possible to develop applications for evaluating the impact of air conditioning and room air on Covid-19. Applications can be developed to investigate the impact of Covid-19 on the environment or humans caused by climate change, contaminated water, or the sewage system. We can develop applications for smartphones that can quickly and accurately identify Covid-19 using algorithms based on a person's condition, such as image, sound, or skin temperature. It is possible to develop applications that examine the effects of Covid-19 on the people of a country and in comparison, to the people of other countries, as well as the effects of race, gender, and age.

New algorithms new algorithms must be proposed for the detection and prevention of Covid-19. Different Covid-19 variants can be classified using deep learning and machine learning classifiers with enhanced prediction capabilities. AI-based algorithms, such as the Capsule Network, CNNs, and GRAD-CAM, can be utilized more effectively. These adaptable algorithms can act autonomously in accordance with the new circumstances of the future variants of Covid-19. These algorithms should be studied and funded.

Long Covid Although there are hypotheses regarding the "long Covid" complication, this form of Covid-19 disease remains unknown. People infected with Covid-19 have experienced long Covid symptoms, which include fatigue and shortness of breath after recovery. For this reason, scientists must acquire more information about this disease as quickly as possible. Using a combination of computer-based modeling and clinical trials, researchers can identify long Covid complications and recommend the most effective drugs to treat them. Scientists can also create algorithms that predict long Covid in individuals who have previously experienced it.

Economic impacts The widespread of the Covid-19 virus is threatening the health and livelihoods of people all over the world. Most economists believe that the epidemic of this virus has had a significant negative impact on the level and various economic, social, and livelihood dimensions of many countries, particularly the least developed ones. Therefore, it is necessary to create computer programs to assess the impact of Covid-19 on various economic sectors and to forecast future economic conditions. The provision of services is one of the industries negatively affected by the global spread of Covid-19. Numerous countries have imposed temporary shutdowns and quarantines. Many people work from home, so it will be necessary to develop the infrastructure and provide suitable computer programs for these individuals. In addition, if the severity of this disease increases and it becomes an epidemic in the future, travel restrictions, the cancellation of sporting events and the prohibition of gatherings, as well as people not using public transportation and public spaces such as restaurants, shopping malls, and museums, will deal a severe blow to the economy. Therefore, computer-based programs should be developed to mitigate this disease's impact on service-based economies.

6 Conclusion

This review discusses an SLR-based method for combating Covid-19 based on computer-aided methods in prevention, detection, and service provision approach. This study aims to investigate existing computer science-based methods to combat Covid-19. This paper has reviewed previous studies, their challenges, and their solutions. It has summarized the side-by-side comparisons between the applied approaches in a table to provide a quick and accurate understanding. As a result of a robust study conducted over the past three years by researchers across various disciplines, we identified several issues and directions for future research. First, several infectious diseases could be detected using computer-assisted detection methods delineated in our study, which others can customize for specific illnesses otherwise Covid-19. Second, we have discovered the tremendous potential in studying smart cities, homes, workplaces, and hospitals using advanced intelligent technologies such as IoT and distributed systems. Finally, we will examine service composition in intelligent healthcare systems in a separate paper, as others can do it. Among the limitations of this literature is the absence of non-English or non-peer-reviewed articles, book chapters, and conferences.

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Availability of data and material Not applicable'.

Declarations

Conflicts of interest There is no conflict of interest.

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