IoT and AI Technology Used for COVID-19 Pandemic Control

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Abstract. The pandemic of COVID-19 is going on spreading in 2021, which has infected at least 170 million of people around the world. The healthcare systems are overwhelmed due to the virus infection. Luckily, Internet of Things (IoT) is one of the most effective paradigms in the smart world, in which artificial intelligence technology, like cloud computing and big data analysis, is playing a vital role in epidemic prevention and blocking COVID-19 spreading. For example, in terms of remote screening and diagnosis of the COVID-19 patients, AI technology based on machine learning and deep learning has significantly upgraded recently medical equipment and reshapes the workflow with minimal contact to patients, therefore medical specialists can make clinical decisions more efficiently, providing the best protection not only to patients but also specialists themselves. This paper hereby reviews the latest progress of IoT systems combined AI against COVID-19, and it also provide comprehensive detail on how to overcome the epidemic challenges along with directions towards the possible technology trends for future work.

Keywords: Internet of Things · COVID-19 · Epidemic prevention

1 Introduction

Coronavirus disease 2019 was officially named 'COVID-19' by the World Health Organization in February 2021. Since the first confirmed case of COVID-19, researchers in more than 30 countries and regions around the world have been actively looking for ways to control and treat COVID-19. As the latest and hottest technology in the 21st century, the Internet of Things system can realize data information, remote control and intelligent management and monitoring through real-time network. Therefore, it is of great significance to apply IoT technology to clinical medicine, especially in this context, to apply IoT technology to COVID-19 epidemic prevention and control work.

The use of IoT prevention and control systems to control COVID-19 is not only for patients, but also for the general population. People can use wearable devices to self-monitor, observe and record their respiration rate, heart rate, daily temperature and other physiological values, so as to make self-judgment. Even in isolation, they can quickly detect changes in vital signs. More noteworthy is that the application of the Internet of

S. Wang et al. (Eds.): IoTCare 2021, LNICST 415, pp. 497–507, 2022.
https://doi.org/10.1007/978-3-030-94182-6_40

Things in clinical medicine can promote the development of modern intelligent medical care, especially in remote screening, intelligent diagnosis and other aspects. Remote screening eliminates the need to screen large numbers of people in the emergency room, thereby reducing the possibility of exposure. Intelligent diagnosis solves the problem of slow speed and low accuracy of manual reading image scan report. Smart diagnostics serve as an auxiliary tool to help frontline physicians quickly determine if a patient is infected with COVID-19, so that patients can be isolated for further treatment in the first place. The application of Internet of Things technology in epidemic prevention and control not only avoids person-to-person contact and reduces the possibility of cross-infection, but also achieves precise treatment and prevention and control.

The second part below introduces the new epidemic prevention and control methods: wearable devices with Wi-Fi, 5G and Bluetooth technology as the main technologies; The third part introduces the method of remote screening. The fourth part discusses the methods of intelligent diagnosis, and the last part summarizes and looks into the future of medical technology in the Internet of Things. With the help of artificial intelligence, these new IoT technologies will drive the development of modern epidemic prevention and control. This review mainly discusses the advantages and disadvantages of different methods in remote screening and intelligent diagnosis based on COVID-19 related studies before April 31, 2021, hoping to provide some help and guidance for doctors and researchers in overcoming COVID-19.

2 New Methods for COVID-19 Prevention and Control - Wearable Devices

Wearable technology, first developed at a MIT lab in the 1960s, embedding technologies such as multimedia, sensors and wireless communications into people's clothing. Novel coronavirus wreaked havoc worldwide, wearable devices based on IoT systems are used to measure COVID-19-related signs, such as respiratory rate and body temperature. M. N. Mohammed et al. [1] propose the use of a smart helmet with a mounted thermal imaging system to automatically detect coronavirus through the thermal imaging system, thereby reducing the contact between people. There will be a positioning system in the smart helmet. When a temperature higher than normal is detected, the system responds, and the location system module immediately marks and determines the geographic location, while sending a notification to the designated smartphone via GSM. That way, health care workers can get timely data on people's temperature. However, as the second-generation mobile communication system, the Global System for Mobile Communications (GSM) has fallen behind the new era of 5G technology. Barbara Fyntanidou's team [2] has developed a wrist-worn wearable device that uses advanced digital signal processing algorithms to continuously extract heart rate, oxygen saturation, body temperature estimates, and more. Like smart helmets, wrist-worn wearables can transmit processed data to an app or designated third-party mobile port in a timely manner through mobile communication protocols. Muhammad Usman Ashraf et al. [3] propose an intelligent limbic system, as shown in Fig. 1, which is based on wearable devices to detect those at risk of infection. The system makes use of a wearable module equipped with infrared and pulse sensors to calculate body temperature and pulse rate in real time, and an unwearable module to monitor respiratory and blood pressure data of suspected patients by placing them in crowded places such as airports and large shopping malls. The two modules work with each other and alert each other when a suspected case occurs in any public place. But it's hard to guarantee that the unwearable modules are installed in the public places suspected patients have visited. Meanwhile, the placement of modules also brings some security risks. Luca Lonini et al. [4] use a soft wearable sensor device attached to the body, placed in the sternal incision, to receive respiration, heart rate and other data. Wearable sensors provide a novel way to detect COVID-19, which depends on recording changes in heart rate, respiration, cough, and body temperature over a long period of time to determine the coronavirus infection. These technologies, as well as data networks, mainly rely on Wi-Fi, 5G, Bluetooth technology, but only relying on such a network for continuous monitoring may lead to low accuracy and data loss problems.

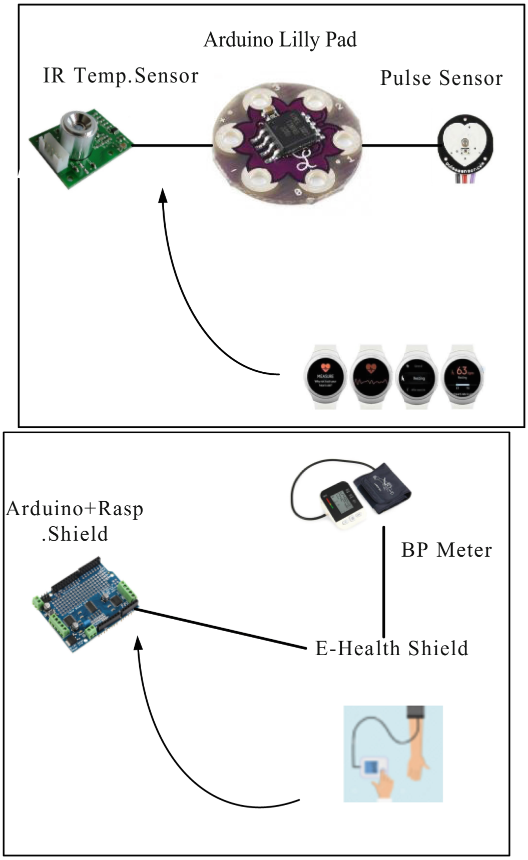

Fig. 1. Wearable device and non-wearable device module device. Wearable gadget on the left and Non-wearable gadget on the right.

Wearable devices are widely used on COVID-19 to measure the health status of potential infected people and self-detect physiological changes during isolation. Wearable devices use GPS data to track location, so doctors can easily track a patient's condition, for example, the intelligent helmet proposed by M. N. Mohammed et al. [1], which uses the intelligent helmet with a mounted thermal imaging system to automatically detect coronavirus from thermal images without the need for human intervention. This saves time and reduces human interactions that could cause the coronavirus to spread more quickly. Wearable devices such as smartwatches can also be accustomed to collect self-reported symptom-tracking data to distinguish between negative and positive cases among infected people. Wrist-worn devices could be used specifically for emergency situations, such as prioritizing and classifying emergency patients. The 3D wearable prototype design proposed by Nizar Al Bassam et al. [5] includes wearable body sensors, network application programming interface layer and mobile frontend layer, which is also the use of a portable wearable device to build an automated healthcare system. One of the advantages of the healthcare system is that COVID-19 can be detected at an early stage. Figure 2 is the architecture of the system. The wearable sensor layer is accustomed to measure temperature, heartbeat, oxygen saturation and cough technology. Compared with the intelligent limbic system of Muhammad Usman Ashraf et al. [6], this system improves the GPS location data of patients to medical units in real time, which makes it more convenient and effective to monitor patients and suspected patients, and is more suitable for responding to emergency situations. When the patient violates the self-isolation rules, the device will immediately send an alarm and notification signal. In the future, wearable devices based on the Internet of Things technology will provide various methods to identify, perceive and monitor coronavirus, which has great potential and hope in the healthcare system.

3 Remote Screening Based on IoT

In the context of the COVID-19 pandemic, timely screening infected people as soon as possible is an important measure to prevent and control the epidemic. Obviously, manual screening is very slow, and remote screening technology, can improve the speed and efficiency of screening. Therefore, remote screening based on the Internet of Things system must be developed. Timo Schinkothe team [8] has built a free, IoT-based caregiver cockpit (C19CC), one user is first connected to a healthcare worker, who quickly categorizes the user according to the user's description and color-codes the severity of the examiner. For example, users with red codes are automatically screened and their personal information and recent range of activity are marked. Similarly, patients also have multiple ways to contact the doctor, such as scanning the doctor's QR code. C19CC can not only be used in remote screening, but also can be widely used in remote monitoring, hospital wards, etc. C19CC prescreens patients in a contact-free manner and quickly learns about those who urgently need treatment. Because COVID-19 patients often have fever, in most cases the facial recognition system will also be used to detect the patient and alert the hospital platform via the Internet or mobile devices so that the patient can be isolated and further diagnosed. Weijun Tan et al. [9] propose a basic method based on facial recognition. The main function of this method is to remotely screen out suspicious patients through thermal images, and then retrieve people who have close contact with them through facial recognition system, so as to isolate people in time and prevent the spread of the virus. Although facial recognition can be used for initial remote screening, it is extremely inefficient compared to other methods [29]. The portable scanner proposed by Dennis Hou et al. [10] will input the collected lung ultrasonic images to the platform. After the data is processed by the platform, it will classify the data in the quilt-space network. This sequence of steps allows the screening of patients with and without COVID-19. The classifier could be used on a large scale in nursing homes with adequate budgets, completely avoiding the possibility of infection in elderly people who go to hospital for screening. Cristian Chilipirea et al. [12] design a lightweight Web-based platform that could run on a low-end server infrastructure. The platform consists of a screening application, a data collection module, a machine learning module and a user notification module. The filter application process is designed for smartphone applications and Web pages. This can meet the need for simultaneous screening of multiple people. The data collection module is also available to a large number of simultaneous users. Machine learning modules are used to answer questions about the risk of possible infection. The user notification module is used to send specific messages on demand to inform the user of the outcome, and for those with COVID-19 symptoms, the notification module will inform them of the progression of the disease. However, whether there are malicious attacks on the platform and user information stolen, and how to prevent the abuse of the platform, this is an urgent problem to be solved. Table 1 summarizes the remote screening methods or examples mentioned in this article.

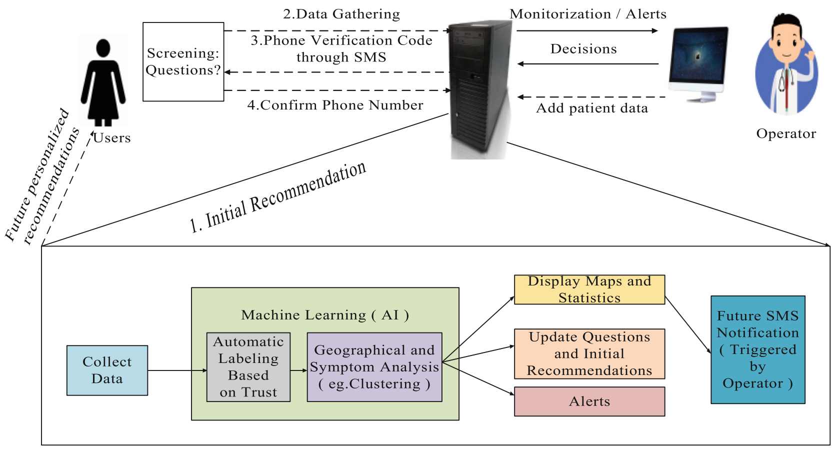

Fig. 2. Shows the architecture of the platform.

Table 1. The methods and results of remote screening mentioned.

Authors	Methods	Results	Features
Timo Schinköthe et al. [8]	The cockpit-C19CC	Identifying telemedicine options can quickly improve patient care	Improve care and safety for people living with COVID-19
Weijun Tan et al. [9]	Facial recognition system using thermal imaging	Ability to identify and track patients	To help control the spread of COVID-19
Dennis Hou et al. [10]	Portable scanner + Subspace multilayer networks	More than 96% of test data accuracy can be obtained	Improve energy efficiency
Cristian Chilipirea et al. [12]	Scalable COVID-19 screening platform	Data can be collected and analyzed for more than 200,000 people per minute	The main feature is the use of distributed, lightweight design

4 Intelligent Diagnosis of COVID-19

It is well known that X-ray and CT scans are the two standard methods for diagnosing COVID-19. But in the context of the outbreak of novel coronavirus, there are signs of cross-infection between actual CT and X-rays, which can put suspected patients and doctors at risk. At the same time, only reading a large number of image scans and manually drawing the outline of lung lesions will lead to the delay of COVID-19 diagnosis [30, 31]. Therefore, it is of great significance to develop an intelligent diagnostic system based on the Internet of Things system, which can assist front-line doctors and jointly fight against COVID-19.

Common chest CT findings of COVID-19 patients include ground glass opacity [11], consolidation, pleural effusion, etc. Figure 3 shows CT images of patients with COVID-19 at different periods and normal subjects. As shown in the figure, the CT manifestations of the lungs are often patchy or diffuse ground glass shadows in the early stage. In the progressive stage, the two lung diseases progress rapidly, multiple lesions fuse into large sheet consolidation, and the lesion density increases [13]. In the absorption phase, the lesion range was slightly reduced, the density was reduced, and the fibrous cord shadow was visible. X-ray images of patients with COVID-19 are typically characterized by large and blurred lungs, as shown in Fig. 4. It may be accompanied by thickening of the cleft system at night and a small amount of pleural effusion. When the disease is more severe, diffuse consolidation shadows can be seen in both lungs, with white lungs and pleural effusion.

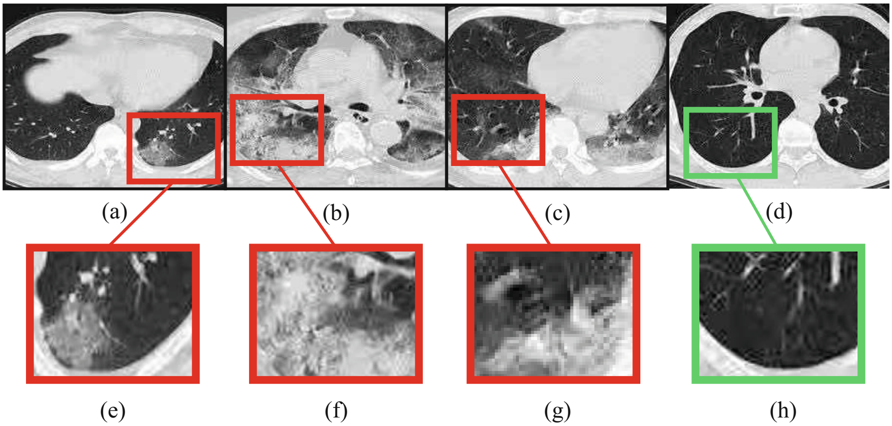

Fig. 3. Chest CT images of laboratory-confirmed COVID-19 patient and 1 healthy subject. Patients' GGOs are highlighted in red borders and normal subjects' GGOs are highlighted in green borders. (a), (b) and (c) lung CT images of COVID-19 patients in the early, advanced and absorptive stages, respectively; (e), (f) and (g) are the parts of GGO in these three stages respectively. (d) is a CT scan of a normal lung, and (h) is a local magnification of a normal lung.

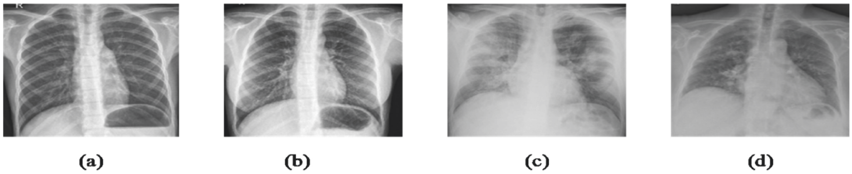

Fig. 4. (a) (b) is the CXR image of normal people, (c) (d) is the CXR image of COVID-19 patients [7, 14].

The premise of intelligent diagnosis by X-ray and CT scanning is image segmentation. The goal of segmentation is to separate the area or object of interest from the rest of the body for fixed-point measurement. Kai Gao et al. [15] develop a dual-branch combinatorial network (DCN) for combinatorial segmentation and classification. Ramin Ranjbarzadeh et al. [16] propose a dual-path convolutional neural network for detecting and classifying COVID-19 infections by extracting global and local features. Fan et al. [17] use the Deep Network for Pulmonary Infection Segmentation (INF-NET) to automatically segment infected tissue in sections. Naveen Paluru et al. [18] propose a lightweight CNN (ANAM-NET) based on deformation deep embedding for the segmentation of anomalies in COVID-19 chest CT images. All of these methods can automatically segment the scanned image. As lung segmentation technology becomes more and more mature, intelligent diagnostic COVID-19 will also become more reliable.

Qian Tang et al. [19] use neural network and digital image processing technology to design a lightweight classification model based on inter-section and intra-section attention mechanism, which integrates early screening, lesion assessment, lesion segmentation, and histogram of pixel distribution of lung and lesion. The average diagnosis time per person in this algorithm model is only 0.4 s. Zhengfeng Jiang's team [20] trains a VGG-16 Convolutional Neural Network migration to build an intelligent COVID-19 diagnostic model, which is based on a small sample data set and uses CT scan images to distinguish which stage of COVID-19 patients are in early stage, advanced stage, and severe stage. However, Buyut Khoirul Umri et al. [21] express that CNN had more significant advantages compared with VGG-16, and they proposed to combine CNN and Clahe to detect novel coronavirus in X-ray images. Contrast-constrained adaptive histogram equalization and convolutional neural network were used to analyze the data sets. Juliana C. Gomes et al. [22] propose an intelligent system to support X-ray scan image diagnosis and developed IKONOS (a desktop application) to diagnose COVID-19 via X-ray image, this is shown in Fig. 5. After receiving the image, the doctor uploads the image to the app, which uses texture and shape descriptors and classical classifiers for feature extraction, which is analyzed by the intelligent system to identify COVID-19. Similarly, Ali Nevin et al. [23] also use the RESNET-50 model of Convolutional Neural Network (CNN) to carry out diagnostic research. With the help of the supervised learning method based on statistical learning theory (SVM algorithm), they could also directly extract features to determine whether there is a disease [32]. The sensitivity of their experiment is higher than that of Juliana C.Gomes et al. [22], which will make it easier for doctors to reduce the rate of missed tests. Krishna Kant Singh et al. [24] put forward an improved deep convolutional neural network for automatic diagnosis of COVID-19. The advantages brought by the combination of wavelet transform and deep network can be widely used to diagnose COVID-19 from chest X-ray images. The performance of this method is superior to the common methods, and it can be used for the early treatment and diagnosis of COVID-19 disease [28]. Sivaramakrishnan Rajaraman et al. [25] demonstrate how an iteratively built set of deep learning models could be used to intelligently diagnose COVID-19 via chest X-rays. Their combined use reduces the complexity of the model and the variance of the prediction values, thus promoting the adoption of digital chest radiograph detection COVID-19. Diego Hernandez et al. [26] introduce the trained deep learning model in advance, and then designed two models (RESNET-50 and VGG-16) to extend CNN. Although there were many mistakes in the actual prediction, this study also provided a new idea of intelligent diagnosis. Jun Wang et al. [27] propose a CT image scanning based model for diagnosing COVID-19. Specifically, it is a prioritized attention residual learning (PARL) module that training the 3DRESNET branch as a binary classifier for lung images. Its greatest advantage is that it can highlight the lesion area in the lung. With this advantage, this framework model can not only be widely used in the early intelligent diagnosis of COVID-19, but also can be applied to other computer-aided detection, such as glaucoma and skin lesions in retinal fundus images. The intelligent assisted diagnosis model proposed by Zhengfeng Jiang et al. [20], with its extremely high sensitivity and high reliability in small data based on learning transfer technology, can quickly provide doctors with reference information and improve efficiency during epidemic prevention and control period. However, this method still has the problem of insufficient sample size and needs to be expanded.

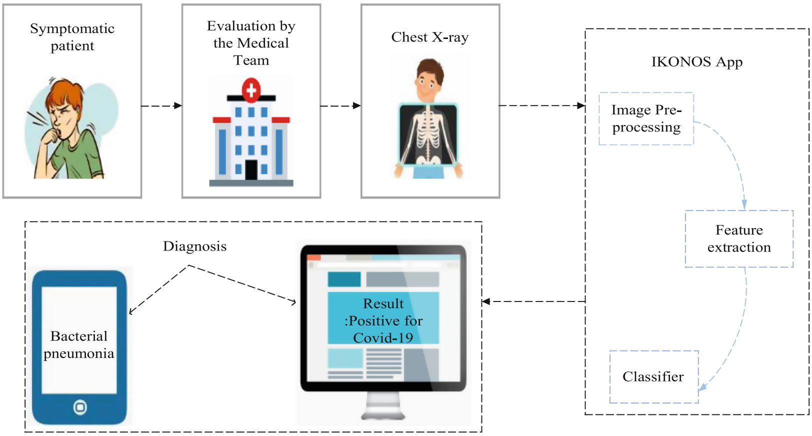

Fig. 5. Chest X-rays of symptomatic patients can be loaded into IKONOS. The application consists of an intelligent system capable of extracting features and classifying images. The results can be viewed on the computer on which the software is installed.

5 Conclusion and Future

Although COVID-19 has affected more than 30 countries and regions around the world, the good news is that the 21st century is an advanced scientific era. Researchers are working to make new breakthroughs in COVID-19 screening, diagnosis, and monitoring. Intelligent technology based on IoT systems has proven to be an extremely valuable resource, with applications ranging from wearable technology to COVID-19 remote screening and intelligent diagnostics. They are also discussed separately in this article. Wearable devices make it easy to measure an individual's health status and provide timely feedback to the hospital unit through a positioning system. Remote screening can avoid the mutual contact between medical personnel and screeners, improve screening efficiency, and realize early screening and early isolation. Smart diagnostics can quickly identify COVID-19 through X-ray and CT scans, reducing the workload of front-line doctors and enabling patients to receive treatment as quickly as possible. From then on, artificial intelligence image acquisition will enable patients to obtain high-quality images even at low radiation levels.

In the future, there will be more intelligent technologies based on the Internet of Things to fight human epidemics. For example, the use of cloud technology to achieve COVID-19 screening, diagnosis, monitoring and other integration. It is hoped that by integrating algorithms to predict risk events and take quick actions, the processing effect can be improved at the fastest and most efficient speed. Meanwhile, some intelligent systems of the Internet of Things can be built to automatically repair loopholes and problems.

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