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Survey paper

Review on the COVID-19 pandemic prevention and control system based on AI

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ABSTRACT

As a new technology, artificial intelligence (AI) has recently received increasing attention from researchers and has been successfully applied to many domains. Currently, the outbreak of the COVID-19 pandemic has not only put people's lives in jeopardy but has also interrupted social activities and stifled economic growth. Artificial intelligence, as the most cutting-edge science field, is critical in the fight against the pandemic. To respond scientifically to major emergencies like COVID-19, this article reviews the use of artificial intelligence in the combat against the pandemic from COVID-19 large data, intelligent devices and systems, and intelligent robots. This article's primary contributions are in two aspects: (1) we summarized the applications of AI in the pandemic, including virus spreading prediction, patient diagnosis, vaccine development, excluding potential virus carriers, telemedicine service, economic recovery, material distribution, disinfection, and health care. (2) We concluded the faced challenges during the AI-based pandemic prevention process, including multidimensional data, sub-intelligent algorithms, and unsystematic, and discussed corresponding solutions, such as 5G, cloud computing, and unsupervised learning algorithms. This article systematically surveyed the applications and challenges of AI technology during the pandemic, which is of great significance to promote the development of AI technology and can serve as a new reference for future emergencies.

1. Introduction

In December 2019, in the city of Wuhan in the province of Hubei, many cases of severe pneumonia from an unknown cause were reported. An analysis of lower respiratory tract samples revealed a clear illness caused by a novel virus named novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by the World Health Organization. The coronavirus disease 2019 (COVID-19) pandemic has become a global emergency, producing tragedies worldwide and causing unpredictability in economic damages. As of August 22nd, 2021, there were 211,993,378 confirmed cases and 4,432,648 deaths worldwide. Furthermore, according to incomplete statistics, more than five thousand people die from COVID-19 every day worldwide. This outbreak has been ongoing for almost a year and a half and is continuously spreading. These data indicate that COVID-19 is out of control, and scientifically responding to major emergencies, such as COVID-19, has become a subject deserving serious consideration.

During the pandemic, IHME COVID-19 forecasting team (2021) use COVID-19 case and mortality data from 1 February 2020 to 21 September 2020 and a deterministic SEIR (susceptible, exposed, infectious, and recovered) compartmental framework to model possible trajectories of SARS-CoV-2 infections and the effects of non-pharmaceutical interventions in the United States at the state level from 22 September 2020 through 28 February 2021. Their experimental results show that achieving universal mask use (95% mask use in public) could be sufficient to ameliorate the worst effects of pandemic resurgences in many states. (Wang et al., 2020b) evaluated the antiviral efficiency of five FAD-approved drugs including Ribavirin, Renciclovir, Nitazoxanide, Nafamostat, Chloroquine, and two well-known broad-spectrum antiviral drugs Remdesivir (GS-5734) and Favipiravir (T-705) against a clinical isolate of 2019-nCoV in vitro. And their findings reveal that remdesivir and chloroquine are highly effective in the control of 2019-nCoV infection in vitro. In addition, Altan and Karasu (2020) proposed a hybrid model consisting of two-dimensional (2D) curvelet transformation, chaotic salp swarm algorithm (CSSA), and deep learning technique to determine the patient infected with coronavirus pneumonia from X-ray images. Their results show that the proposed hybrid model can diagnose COVID-19 disease with high accuracy from chest X-ray images. To some extent, these studies can contribute to the battle against the pandemic. In addition, researchers have summarized the application of big data (Bragazzi et al., 2020; Pham et al., 2020; Lin and Hou, 2020), intelligent equipment and systems (Sonn et al., 2020; Costa and Peixoto, 2020; Inn, 2020), intelligent robots (Yang et al.,

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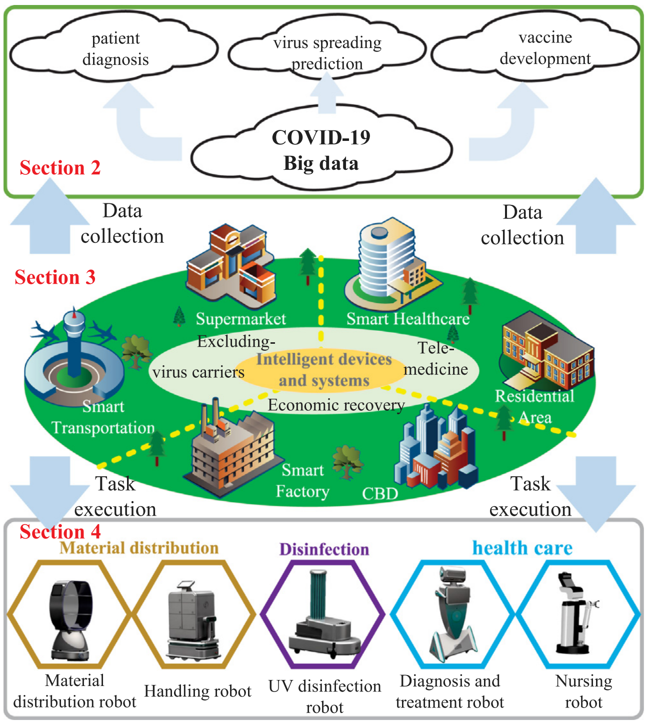

Fig. 1. AI-based smart pandemic prevention and control system.

2020) in the pandemic. In reality, all of these tasks are inextricably linked to the use of AI technology. AI is the study of programming computers to replicate certain human thinking processes and intelligent behaviors such as learning, reasoning, thinking, and planning. AI primarily comprises the idea of computer intelligence realization, i.e. creating computers whose intelligence is similar to human brain intelligence and allowing computers to reach higher-level applications (Hassabis et al., 2017). Vaishya et al. (2020) simply summarized the application of AI in the pandemic, i.e. early detection and diagnosis of infection, monitoring treatment, contact tracing of individuals, case and mortality projections, drug and vaccine development, reducing the workload of healthcare workers, and disease prevention. In addition, papers (McCall, 2020a; Naudé, 2020) also briefly introduced the role of AI in COVID-19. Paper (Naudé, 2020) reviewed the application of machine learning based AI in COVID-19. Those reviews (Vaishya et al., 2020; McCall, 2020a; Naudé, 2020; Alimadadi et al., 2020) have provided an early overview of the AI achievements.

However, a detailed analysis from the AI technology perspective remains lacking. Therefore, it is necessary to discuss the key AI technologies combating the pandemic and identify future research trends. In this study, a literature review is carried out with the goal of carefully analyzing the research achievements thus far. We carefully investigated the application of AI and looked forward to its future development. The main contributions of this paper are as outlined below. (1) We detailed the use of AI in the pandemic from the following three perspectives: COVID-19 big data, intelligent equipment and systems, and intelligent robots, including virus spreading prediction, patient diagnosis, vaccine development, excluding potential virus carriers, telemedicine service, economic recovery, material distribution, disinfection, and health care. These perspectives have significant practical implications for the future direction of follow-up work in the fight against COVID-19 and the prevention and response to catastrophic emergencies. (2) We discussed the future development of AI technology, such as 5G and cloud computing, which also contributes to the advancement of AI technology, as well as the advanced development of related fields such as big data, intelligent equipment and systems, and intelligent robotics.

As mentioned in Fig. 1, this article systematically analyzes the use of AI in COVID-19 big data, intelligent equipment and systems, and intelligent robotics during the pandemic in Sections 2, 3, and 4, respectively. This figure shows that AI technology plays a link in the process of pandemic prevention and control, which can connect different technical fields (Sections 2–4) into a comprehensive system. Furthermore, AI has various applications in mentioned technical domains, like the AI-based intelligent robots can achieve autonomous material distribution, disinfection, and health care. The AI-based intelligent pandemic prevention and control system could assist or replace humans in cumbersome and monotonous tasks with advanced technologies. And Sections 2–4 specifically introduced the detailed applications. Section 5 further explores the future development of AI-based pandemic prevention and control systems. Finally, we conclude with a summary of the paper in Section 6.

2. COVID-19 big data with AI

Multisource big data in areas such as health, economics, and social interaction have exploded in recent years because of the rapid expansion of the Internet, intelligent equipment and systems, and other scientific and technological domains. Unlike traditional data, big data refers to large-scale growth data sets, including heterogeneous formats such as structured, unstructured, and semi-structured data. Big data has a complex nature and demands powerful technology and advanced algorithms for processing (Oussous et al., 2018). Moreover, big data has applications in various areas of the intelligence industry, including smart grids, smart medical care, and smart transportation (Dubey et al., 2019; Iqbal et al., 2020). In the context of COVID-19, big data refers to the patient, care data such as physician notes, X-ray reports, case history, list of doctors and nurses, and information of outbreak areas (Pham et al., 2020). Because of cloud computing and rapid GPU development, the AI computing power has greatly improved, and AI-based effective data processing methods have become the mainstream direction (Zhang et al., 2018). This paper by Ienca and Vayena (2020) proposed that using big data to fight against COVID-19 is reliable and significant. As Fig. 2 shows, it is possible to achieve virus spreading prediction (Section 2.1), rapid patient diagnosis (Section 2.2), and vaccine development (Section 2.3) using AI technology to process COVID-19 big data. Fig. 2 simply depicts the mentioned three tasks. Especially, the deep learning model is a powerful computer-aided diagnosis tool, which can rapidly achieve the patient's diagnosis. This section mainly discusses the specific application of AI in COVID-19 big data.

2.1. Virus spreading prediction

According to prior research by Lauer et al. (2020), the COVID-19 virus has a median incubation time of 5.1 days, and 97.5 percent of patients experience symptoms within 11.5 days of infection. Before the outbreak of COVID-19, there was a long incubation period. If the government can implement prompt scientific preventive steps during the virus's incubation phase, the outbreak of a pandemic can be avoided to some extent. Individuals can also take precautionary steps as soon as possible to safeguard themselves if they have enough information about the virus's transmission power, manner of transmission, and sources of transmission. As a result, it is critical to use COVID data to develop an appropriate model that could be used to track the virus's progression.

To forecast how the virus's distribution will alter over time, Kucharski et al. (2020) integrated the random transmission model with COVID-19 local case data and foreign cases from Wuhan. Specifically, these authors fitted a stochastic transmission dynamic model to multiple publicly available datasets (daily number of new internationally exported cases and daily number of new cases in Wuhan with no market exposure) of cases in Wuhan and internationally exported cases from Wuhan. On the one hand, this method is overly reliant on datasets; on the other hand, the model is greatly impacted by both

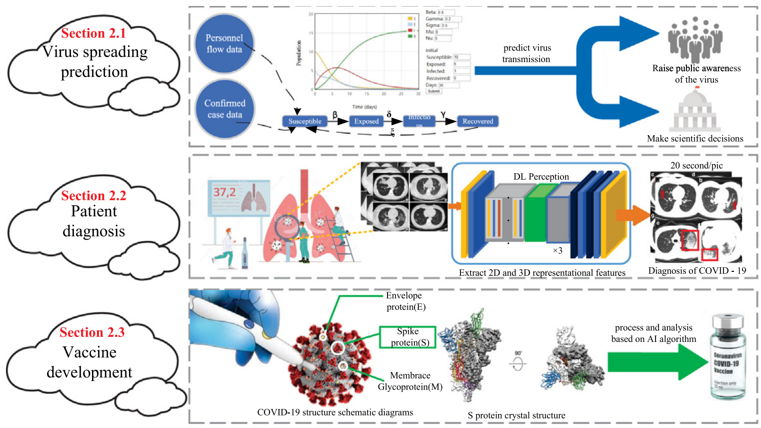

Fig. 2. Applications of AI in COVID-19 big data.

preventive and control efforts and virus changes, and thus is unable to properly anticipate pandemics. By studying data of COVID-19 cases and personnel movement data, Wu et al. (2020a) developed a susceptible–exposed–infectious–recovered metapopulation model. The fundamental equations that the authors considered are based on the SEIR model as follows:

$$\frac{\mathrm{d}S(t)}{\mathrm{d}t} = -\frac{S(t)}{N}\left(\frac{R_0}{D_I}I(t) + z(t)\right) + L_{I,W} + L_{C,W}(t) - \left(\frac{L_{W,I}}{N} + \frac{L_{W,C}(t)}{N}\right)S(t) \quad (1)$$

$$\frac{\mathrm{d}E}{\mathrm{d}t} = \frac{S(t)}{N}\left(\frac{R_0}{D_I}I(t) + z(t)\right) - \frac{E(t)}{D_E} - \left(\frac{L_{W,I}}{N} + \frac{L_{W,C}(t)}{N}\right)E(t) \quad (2)$$

$$\frac{\mathrm{d}I(t)}{\mathrm{d}t} = \frac{E(t)}{D_E} - \frac{I(t)}{D_I} - \left(\frac{L_{\mathrm{W,I}}}{N} + \frac{L_{\mathrm{W,C}}(t)}{N}\right)I(t) \quad (3)$$

where S(t), E(t), I(t), and R(t) are the numbers of susceptible, latent, infectious, and removed individuals, respectively, at time t; D_E and D_I are the mean latent and infectious periods; R_0 is the basic reproductive number; $L_{W,C}(t)$ and $L_{C,W}(t)$ are the daily number of all domestic outbound and inbound travelers; $L_{W,I}$ and $L_{I,W}$ are the daily average number of international outbound and inbound air passengers; and z(t) is the zoonotic force of infection, which equals to 86 cases per day in the baseline scenario before market closure on Jan 1, 2020, and equals 0 thereafter. The public could be sufficiently aware of the virus's hazards as a result of the establishment of these mathematical models. These models may also be used by government agencies to make scientific judgments.

As a beneficial tool for data processing in recent years, AI technology has been critical for processing COVID-19 big data. The adoption of AI technology and the utilization of a large amount of pandemic data for scientific modeling and optimization have been critical, especially during the pandemic's incubation period, for identifying the source of infectious diseases and predicting the pandemic's development trend and spread. Hu et al. (2020a) developed a modified stacked autoencoder for modeling the transmission dynamics of pandemics. By using the latent variables in the autoencoder and clustering algorithms, this method can group the provinces/cities to investigate the transmission structure. Yang et al. (2020b) incorporated COVID-19 epidemiological data into the SEIR model to derive the pandemic curve and used a long short-term memory (LSTM) model trained on 2003 SARS data to predict the pandemic. The model selected the Adam optimizer, which uses a training wheel designed for 500 epochs, a batch size of one, and a loss function selected on the basis of the mean square error (MSE) according to per the following equation:

$$MSE = \frac{\sum_{i=1}^{n}\left(y_i - \hat{y}_i\right)^2}{n} \quad (4)$$

where the y_i and $\hat{y}_i$ are the label and model predicted values, respectively. The n is the number of 2003 SARS data samples. The dynamic SEIR model was effective in predicting the COVID-19 pandemic peaks and sizes. And the AI-based model trained on past SARS dataset also shows promise for future prediction of the pandemics.

Feng et al. (2021) proposed an SEIR model to analyze the pandemic trend in Wuhan and used the AI model to analyze the pandemic trend in non-Wuhan areas. In the DNN and RNN model, two layers of the recurrent neural network were built to extract the deep features of the data, and one layer of the deep neural network was used to output the results. The results show that the proposed AI model which added population migration data could well predict the pandemic situation in non-Wuhan areas in China with a large number of input infections. This approach efficiently extracts COVID-19 data characteristics by utilizing the strong data representation capabilities of neural networks. However, they did not consider the parameter fluctuation caused by the possible super disseminator and virus variation in the SEIR model, and the potential impact of other factors on COVID-19 in the DNN and RNN model. Wang et al. (2020a) implemented multiple recurrent neural network-based deep learning models and combined them using the stacking ensemble technique. In addition, these authors developed clustering-based training for high-resolution forecasting to overcome the sparsity of training data and solve the disease's dynamic correlation. Clearly, stacking several deep learning models improves the model's prediction accuracy. But, the high model complexity of spatial temporal models may bring overfitting problem. Furthermore, Wang et al. (2019) proposed deep learning-based pandemic forecasting with synthetic information (DEFSI), which is a pandemic forecasting framework that integrates the strengths of artificial neural networks and causal methods. In the DEFSI framework, surveillance data are used to construct a region-specific disease parameter space. Subsequently, simulations parameterized by samples from the parameter space generate synthetic training data consisting of both state and county level weekly ILI incidence curves. Synthetic data are used to train a two-branch deep neural network model. During the forecasting process, the trained model uses surveillance data as input. DEFSI achieved better performance than the state-of-the-art methods on state-level forecasting and consistently better performance than others on county-level forecasting. In addition, further research combining observational data with extensive data obtained by sociological, epidemiological, and behavioral theories could improve the effect of pandemic prediction.

Complementary to the model approach to the transmission dynamics of virus outbreaks, data-driven AI-based methods can provide real-time forecasting tools for viral surveillance and prediction. Compared with traditional modeling methods, these processing and analysis methods combined with AI have significant accuracy advantages. Simultaneously, neural network-based methods involve more complicated model structures and optimization functions. This review by John et al.

(2021) focused on various models, namely, differential equation-based, statistical-based, prediction-based, mixed, machine learning, and deep learning-based models. These authors discussed machine learning and deep learning-based models for diagnosing COVID-19 using radiological images, and the authors emphasized the benefits of deep learning methods. COVID-19 data processing technology coupled with artificial intelligence, has been critical for viral monitoring and prediction in the fight against the pandemic.

2.2. Patient diagnosis

In most cases, nucleic acid testing is used to confirm the diagnosis of COVID-19 patients, and if the test result is positive, the patient can be confirmed. Professional medical personnel are frequently required to assist with this procedure. The significant number of suspected patients causes an enormous diagnostic strain on local hospitals as the pandemic widely spreads, and research investigating effective diagnostic methods is an essential path in the battle against the pandemic. This study by Chung et al. (2020) discovered that COVID-19 patients have unique chest X-ray and computed tomography (CT) imaging features as a result of an increased understanding of the virus's properties and the development of detection technologies. The typical CT findings include bilateral pulmonary parenchymal ground-glass and consolidative pulmonary opacities, sometimes with a rounded morphology and a peripheral lung distribution, which are helpful for radiologists in the detection and diagnosis of this emerging global health emergency. However, chest CT usually contains hundreds of slices, which requires a long time for specialists to diagnose. An AI approach based on a deep convolutional neural network has a strong representation ability in image analysis and can extract semantic information from pictures. This section focuses on AI-based diagnostic methods for promptly diagnosing suspected patients and relieving hospital and medical staff pressure.

The iteration process of neural networks generally necessitates a significant amount of data, and the number of datasets is directly proportional to the network's performance. If the dataset is too small, the network will experience unwanted effects, such as overfitting. Therefore, Cohen et al. (2020) gathered and summarized COVID-19 medical images from websites and publications to aid scholars in better understanding the lung imaging characteristics of individuals with COVID-19.

Based on a dataset of X-ray images from patients with common bacterial pneumonia, confirmed COVID-19 disease, and normal incidents, Apostolopoulos and Mpesiana (2020) used transfer learning to assess the performance of the most advanced convolutional neural network for medical image classification presented in recent years. The results suggested that deep learning with X-ray imaging may extract significant biomarkers related to COVID-19, and the high accuracy, sensitivity, and specificity obtained were 96.78%, 98.66%, and 96.46%, respectively. The final research findings revealed that using a deep learning algorithm with CNNs has a significant impact on extracting major characteristics from X-ray images for the diagnosis of COVID-19. In fact, this method may be constrained by the specific dataset and may only complete the first screening of patients, making it difficult to diagnose patients with minor symptoms. Li et al. (2020b) developed a three-dimensional deep learning model, i.e., the COVID-19 Neural Network (COVNet), which can simultaneously extract representative features of local (2D) and global (3D) chest CT volumetric images for the diagnosis of COVID-19. The author preprocesses a 3D CT exam and used a U-net-based segmentation method to extract the lung region as the region of interest (ROI). Then, the preprocessed image is submitted to COVNet for feature extraction and prediction. The results showed that the proposed model achieved high sensitivity 90% [95% CI: 83%, 94%] and high specificity of 96% [95% CI: 93%, 98%] in detecting COVID-19. The AUC values for COVID-19 and community acquired pneumonia were 96% [95% CI: 94%, 99%] and 95% [95% CI: 93%, 0.97%], respectively. However, the effectiveness of this method in identifying imaging characteristics of other viral pneumonia and COVID-19 remains a concern that requires further investigation.

The use of deep learning frameworks to extract pulmonary imagery and then forward such imagery to the fully connected layer or convolutional layers is an accepted method for a quick diagnosis (Wang et al., 2021; Huang et al., 2020). Shi et al. (2020) introduced intelligent imaging platforms for COVID-19 and summarized popular machine learning methods in the imaging workflow. Moreover, these authors reviewed the use of AI approaches in the diagnosis and segmentation of lesions in medical imaging, such as X-ray and CT, in great detail. These findings demonstrate that the application of AI methods based on lung imaging characteristics is quicker and more efficient than nucleic acid detection and specialized diagnostics.

Since the CT image characteristics of patients with new coronary disease are different from those of other personnels, it is necessary to design a clinical system for diagnosis through CT images. Zhang et al. (2020) proposed an AI-based system that can help distinguish NCP patients from other common pneumonias and can help predict the prognosis of COVID-19 patients. In addition, it can help evaluate drug treatment effects with CT quantification and improve the skill level of junior radiologists. Additionally, Jin et al. (2020) proposed an AI system for fast COVID-19 detection and performed extensive statistical analysis of CTs of COVID-19 patients based on the AI system, which was verified on the dataset.

2.3. Vaccine development

The new advancement of AI in the big data era has paved the road to future rational drug development and optimization, which will significantly impact drug discovery procedures and, eventually, public health (Zhu, 2020). In general, it takes at least a year to produce a new and effective coronavirus vaccination (Thompson, 2020). However, vigorously advancing the research and development of a vaccine is vital for the prevention and control of the pandemic (Graham, 2020; Lurie et al., 2020). Compared with traditional therapeutic antibodies and vaccine development processes, AI can optimize vaccine development and treatment processes.

According to this article by Kaushik and Raj (2020), AI-based technology may predict drugs/peptides directly from the sequences of infected patients, thereby improving affinity for the target and contributing to COVID-19 vaccine design. This research by Bharadwaj et al. (2021) showed AI assistance for structural modeling of unresolved proteins, molecular dynamics simulation (MD) of the modeled protein structure, target finding, selection of B and T cell epitopes, and simulation studies for vaccine development. Because of the powerful fitting ability of neural networks, Abdelmageed et al. (2020) chose the artificial neural network (ANN) method to achieve T cell epitope prediction. Their result shows that ten peptides binding to MHC class I and MHC class II were found to be promising candidates for vaccine design with adequate world population coverage of 88.5% and 99.99%, respectively. In fact, the proposed vaccine needs to be sufficiently validated clinically ensuring its safety and immunogenic profile. Furthermore, Ong et al. (2020) applied the Vaxign reverse vaccinology tool and the newly developed Vaxign-ML machine learning tool to predict COVID-19 vaccine candidates. By applying reverse vaccinology and machine learning, potential vaccine targets can be predicted for effective and safe COVID-19 vaccine development. Hu et al. (2020b) proposed a multitask model to predict potential commercial drugs against COVID-19, and ten drugs are finally listed as potential COVID-19 inhibitors. Additionally, evaluating the therapeutic effect of the combination of drugs usually requires many clinical trials. Ho (2020) proposed that AI be used to optimize combination therapy design, that its effect can outperform existing techniques of drug screening and repositioning, and that it can better play the COVID-19 vaccine's therapeutic effect. It is not difficult to discover evidence that AI based on neural networks is efficient in predicting possible vaccine targets and selecting effective vaccines during the vaccine development process.

Table 1
The application summarize of AI techniques in COVID-19 big data during the pandemic.

R	Applications	Techniques	Key contribution	Ref
1	Virus spreading prediction	Modified stacked autoencoder.	Grouped the provinces/cities to investigate the transmission structure.	Feng et al. (2021)
2	Virus spreading prediction	SEIR and LSTM model.	Predicted the COVID-19 pandemic peaks and sizes.	Yang et al. (2020b)
3	Virus spreading prediction	SEIR, DNN and RNN model.	Predicted the pandemic situation in non-Wuhan areas in China with a large number of input infections.	Feng et al. (2021)
4	Virus spreading prediction	Multiple RNN models.	Solved the problem of diseases dynamic correlation.	Wang et al. (2020a)
5	Virus spreading prediction	DEFSI model.	Achieved better performance than the state-of-the-art methods on state and county level pandemic forecasting.	Wang et al. (2019)
6	Patient diagnosis	Transfer learning, CNN.	The high accuracy, sensitivity, and specificity for the diagnosis of COVID-19 obtained were 96.78%, 98.66%, and 96.46%, respectively.	Apostolopoulos and Mpesiana (2020)
7	Patient diagnosis	U-net, COVNet.	Achieved high sensitivity 90% and high specificity of 96% in detecting COVID-19.	Li et al. (2020b)
8	Patient diagnosis	Machine learning methods.	Introduced intelligent imaging platforms for COVID-19 and summarized popular machine learning methods in the imaging workflow.	Shi et al. (2020)
9	Patient diagnosis	AI-based clinical system.	Predicted the prognosis of COVID-19 patients.	Zhang et al. (2020)
10	Vaccine development	AI-based technology.	Improved affinity for the target and contribute to COVID-19 vaccine design.	Kaushik and Raj (2020)
11	Vaccine development	AI-assistance structure model method.	Improved selection cell epitopes and simulation studies for vaccine development.	Bharadwaj et al. (2021)
12	Vaccine development	ANN model.	Achieved T cell epitope prediction.	Abdelmageed et al. (2020)
13	Vaccine development	Machine learning tool.	Predicted COVID-19 vaccine candidates.	Ong et al. (2020)
14	Vaccine development	Multitask model.	Predicted potential commercial drugs.	Hu et al. (2020b)

2.4. Applications summary

This section lists the AI techniques applications in COVID-19 big data during the pandemic. Table 1 gives the recent AI-based techniques research list in COVID-19 big data during the pandemic. This table contains the techniques and contributions of the citation paper and the author and year information of publication. Specifically, this table concludes the AI application from the virus spreading prediction, patient diagnosis, and vaccine development aspects. Noticeably, the deep learning models, like CNN and RNN, are widely used for prediction tasks in this table. This trend in recent publications depicts investigators working in the deep learning field to develop intelligent process approaches for big data in the future.

3. Intelligent equipment and systems

With the rapid development of sensor technology, computer technology, and communication technology, the speed of the collection, transmission, and processing of multisource information has been qualitatively improved, providing support for the development of intelligent equipment and systems. As Fig. 3 present, the intelligent equipment and systems, like Intelligent voice, temperature measuring devices, and smart medical systems, can improve the process of excluding potential virus carriers and telemedicine services. Fig. 3 lists six intelligent devices or systems that are ordinary in daily life and describes their corresponding applications in the pandemic. When a large pandemic strikes, intelligent equipment and systems play a critical role in telemedicine, economic recovery, and excluding virus carriers. This section mainly discusses this topic in detail.

3.1. Excluding potential virus carriers

Excluding prospective virus carriers in the face of a worldwide pandemic is a way to stop the virus's transmission and keep it from spreading further. However, the virus has impacted a large area, and investigating all personnel is a massive task. Some AI-based equipment and systems have become an important investigation method to replace manual investigation and investigation activity.

Since abnormal body temperature is one of the key indications of COVID-19, measuring body temperature has become an important means for swiftly identifying probable viral carriers. Traditional temperature measurement equipment, such as clinical thermometers and temperature guns, has difficulty satisfying the criteria for quick inquiry because of the high mobility of people in public locations, which may generate crowd congestion and raise the danger of viral cross-contagion. Furthermore, this hand-held conventional temperature measurement equipment requires staff participation in this procedure. To speed up the screening process and avoid contact spread during the screening process, Mohammed et al. (2020) proposed the construction of a system capable of detecting coronavirus automatically from a thermal picture with fewer human interactions utilizing an intelligence helmet with a mounted thermal imaging system. The intelligence helmet uses a combination of thermal imaging and Internet of Things technology to track the screening process and collect data in real time. Furthermore, the system has face recognition technology that may show the pedestrian's personal information and automatically assess the pedestrian's body temperature. For a similar purpose, this paper by Al-Humairi et al. (2020) developed an adaptive monitoring system and model of a smart artificial intelligence helmet based on measuring variables that can be monitored continuously by thermal (Adafruit) and pi (impeded sensor) module cameras with impeded sensors, which can implement body temperature and face detections in real time. As the Medgadget (2020) reported, Northwestern University researchers, in collaboration with the Shirley Ryan Ability Lab, have developed a tiny flexible throat sensor powered by AI technology that can track respiration rate, body temperature, and coughing. The device must be inserted into the patient's throat and aids in the continuous detection of any changes in the patient's condition.

In addition, Imran et al. (2020) presented a ubiquitously deployable AI-based preliminary diagnosis tool for COVID-19, using cough sound via a mobile app. To solve the problem of limited COVID-19 cough data and the misdiagnosis rate induced by complicated dimensions, they employed transfer learning and a multipronged mediator-centered risk-averse AI architecture. The testing results demonstrate that the method has an overall screening accuracy of 95.60%, indicating that it can be utilized as a quick screening tool to exclude probable viral carriers. Although this method is undoubtedly innovative, its performance is

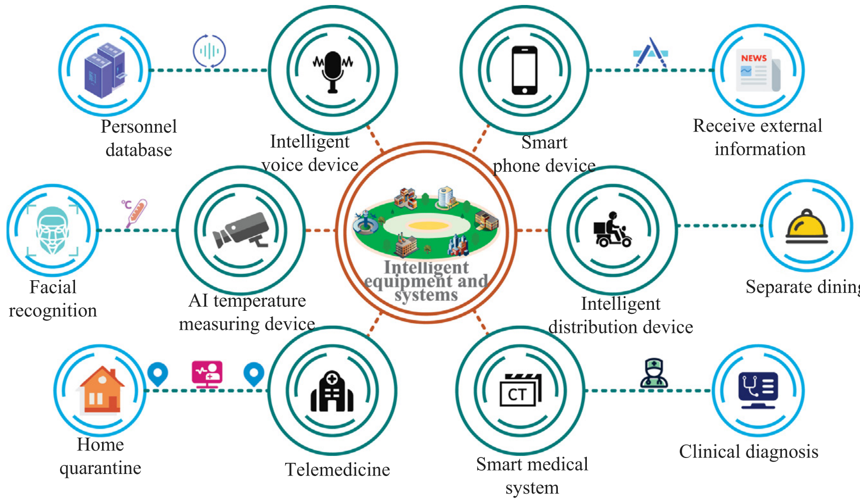

Fig. 3. Application of intelligent equipment and systems in Fighting pandemic.

constrained by the quantity and quality of the dataset. Moreover, it is difficult to distinguish between normal influenza and COVID-19 only based on cough features. Chamberlain et al. (2020) used a network of smart thermometers with more than 1 million users in the United States to determine the propagation of COVID-19 hotspots. It matches real-time data to previous seasonal cold temperature records to determine the COVID-19 transmission hotspots. These AI devices can recognize COVID-19 patients based on anomalous physical indications, and the entire process is contactless, which is critical for pandemic research, prevention, and management.

3.2. Telemedicine service

During the pandemic, a significant number of patients and suspected cases will put tremendous strain on hospitals and other health agencies. Furthermore, when seeing a doctor, moderate patients would have more contact with severe patients, perhaps worsening their condition. As a result, patients with varying degrees of disease should employ diverse treatment techniques, allowing medical resources to be used more efficiently and reducing the rate of contact and infection. Telemedicine can not only provide remote real-time monitoring of patients but can also collect real-time information on their physical conditions to develop appropriate treatment regimens. This can relieve hospital pressure, allocate hospital resources more efficiently, and make the most use of the hospital's limited resources. As a consequence, telemedicine is an essential tool for achieving forward triage (Hollander and Carr, 2020). Furthermore, the government implemented a policy of self-isolation and social distance limits during the outbreak of COVID-19, and remote virtual visits can help hospitals maintain patient follow-up care (Kapoor et al., 2020). Telemedicine has the potential to aid by allowing mildly unwell people to receive supportive treatment while avoiding contact with more seriously ill patients (Portnoy et al., 2020).

By combining the agility and flexibility of AI, telemedicine has exhibited higher capabilities in four areas: patient monitoring, health care information technology, intelligent auxiliary diagnosis, and information analysis and cooperation (Pacis et al., 2018). During COVID-19, Bhaskar et al. (2020) discussed various artificial intelligence and robotics-assisted telemedicine applications and present an alternative AI-assisted telemedicine framework based on an AI engine that searches the network for the best resources within geographical constraints and routes incoming calls to the appropriate node (affiliate). This AI-based telemedicine framework might speed up telemedicine deployment and enhance access to high-quality, low-cost health care, making it a proper answer for the next pandemic breakout. Wu et al. (2020b) attempted to apply a 5G network-based scanning robot to conduct a remote ultrasound examination on COVID-19 patients and explore the feasibility of this teleultrasound diagnosis and consultation technique during critical infectious situations. When a chest CT examination is not feasible, the results demonstrate that robot-assisted television ultrasound can be employed as an effective and practical candidate imaging method.

Tsumura et al. (2021) proposed a 2D teleoperation robotic platform for performing lung ultrasound in COVID-19-infected patients. This approach builds on a simple configuration with low-cost components, high usability with optimized kinematics, and safety features without relying on high-precision sensors. As an evaluation method, they employ the contrast-to-noise ratio of the pleural line to its surrounding area, which is defined as:

$$CNR = \frac{\left|\mu_p - \mu_b\right|}{\sqrt{\sigma_p^2 + \sigma_b^2}} \tag{5}$$

where μ_p and μ_b are the means of the pixel values of the region of the pleural line and background, respectively, and σ_p and σ_b represent their standard deviations. In addition, the feasibility and safety of the method were confirmed in three healthy volunteers. The limitations of this study including that people cannot perform fine adjustment of US probe alignment and contact force actively, and lack of validation and cross-validation of other imaging modalities in COVID-19 patients.

By minimizing the virus's contact rate, telemedicine services can help to lower the virus's infection rate. However, the security of personal private data is a subject worth examining. Behar et al. (2020) presented a short review of remote health monitoring initiatives taken in 19 states during the pandemic. They also discussed the future impact of the pandemic on telemedicine and the issue of data privacy. While the pandemic has undoubtedly posed significant obstacles to the telemedicine system, it also has the potential to encourage the transition of traditional medical procedures and the rapid development of virtual medicine (Wosik et al., 2020).

3.3. Economic recovery

The pandemic has had a significant influence on the city's economy and education. Smartphones and other smart devices and systems are critical to the recovery of economic and social order following the pandemic. People can learn about the latest pandemic information with these smart devices, ensuring their safety. Furthermore, intelligent manufacturing methods can boost production efficiency while also promoting economic recovery and development. Shen et al. (2020) discussed how collaborative intelligent manufacturing technology can help solve the problem of a labor shortage during the pandemic, which caused difficulties in workshop operations. It consists of the five aspects

Table 2
The application summaries of AI-based intelligent equipment and systems during the pandemic.

R	Applications	Intelligent equipment and systems	Key Contribution	Ref
1	Excluding potential virus carriers	Intelligence helmet with a mounted thermal imaging system.	Automatically assessed the pedestrians body temperature.	Mohammed et al. (2020)
2	Excluding potential virus carriers	Adaptive monitoring system and model of a smart AI helmet.	Body temperature and face detections.	Al-Humairi et al. (2020)
3	Excluding potential virus carriers	Tiny flexible throat sensor powered by AI technology.	Tracked respiration rate, body temperature, and coughing.	Medgadget (2020)
4	Excluding potential virus carriers	Transfer learning-based preliminary diagnosis tool.	Diagnosis for COVID-19 with cough sound via a mobile app.	Imran et al. (2020)
5	Excluding potential virus carriers	Network of smart thermometers.	Determined the COVID-19 transmission hotspots.	Chamberlain et al. (2020)
6	Telemedicine service	Telemedicine framework based on AI engine.	Speeded up telemedicine deployment and enhance access to high-quality, low-cost health care.	Bhaskar et al. (2020)
7	Telemedicine service	5G network-based scanning robot.	Remote ultrasound examination on COVID-19 patients.	Wu et al. (2020b)
8	Telemedicine service	2D teleoperation robotic platform.	Performing lung ultrasound in COVID-19-infected patients.	Tsumura et al. (2021)
9	Economic recovery	Automatic payment system with AI vision technology.	Simplify the payment process.	Kim et al. (2021)
10	Economic recovery	Smartphones.	Basis for lifting lockdown policies.	McCall (2020b)
11	Economic recovery	Cross-SEAN system.	Contained the spread of fake information.	Paka et al. (2021)

mentioned below: (1) optimal design of resilient collaborative supplier networks; (2) collaborative planning of manufacturing operations among geographically dispersed manufacturing plants; (3) functional redundancy and dynamic reconfiguration of different shop floors; (4) dynamic intelligent rescheduling of workforces for factory/shop floor operations; and (5) remote testing and maintenance of manufacturing equipment.

Contactless services can decrease consumer–seller contact while also lowering seller labor costs. Kim et al. (2021) presented a fully automated payment system with artificial intelligence vision technology, which employs cameras to construct a vision system to gather photos and uses photographs to train the target detection model. The system has practical application relevance and can be used in fresh food shops, bakeries, and cafeterias on expressways.

Smartphones, being the smart gadget closest to our life, can perform strong activities by downloading a variety of applications, including those related to health care and education. The lockdown is necessary for preventing and controlling the pandemic, but it must be lifted for the economy to recover. Mobile phone data can be used as an important basis for lifting lockdown policies, such as the European Commission recommending a pan-European approach for the adoption of tracing mobile apps using anonymized and aggregated mobile location data (McCall, 2020b). Inadequate understanding of the virus can easily lead to a lack of preventative awareness, resulting in a large-scale outbreak. In our daily lives, mobile phone is one of the primary ways we acquire information from the outside world, and it is also an important tool for spreading awareness about the dangers of viruses. Controlling a pandemic necessitates intensive surveillance, data sharing, and patient monitoring, all of which can be aided by smartphones. In addition, smartphones can be used to control disease spread, since they have connectivity, computing capacity, and hardware to support electronic reporting, epidemiological databases, and point-of-care testing (Udugama et al., 2020). While intelligence device brings convenience to our life, it has been accompanied by a tsunami of fake news and misinformation. This fake news and misinformation may cause unnecessary confusion among the public. To contain the spread of such information, Paka et al. (2021) introduced a large-scale COVID-19 Twitter fake news dataset (CTF) and proposed a cross-stitch based semi-supervised end-to-end neural attention model (Cross-SEAN). Cross-SEAN employed cross-stitch units for optimal sharing of parameters among tweet features and user features and used Maximum likelihood and adversarial training for supervised loss. The results show that the Cross-SEAN model can achieve a 95% F1 Score on the CTF dataset. It is meaningful to study the role of fake news and misinformation using AI models.

Iyengar et al. (2020) conducted a comprehensive review of the literature using appropriate keywords on the PubMed, SCOPUS, Google Scholar, and ResearchGate search engines and discussed the role, common applications, and support for telemedicine technology in several aspects of the current COVID-19 pandemic. In general, smartphones allow medical professionals and patients to avoid face-to-face contact, maintain social distance, and prevent the spread of the virus. Smartphones are also useful for clinical examination, diagnosis, prompt advice, prescriptions, and patient monitoring at home and in remote locations. It is clear that, in addition to guaranteeing people's safety, these smart devices and systems are critical to society's economic revival.

3.4. Applications summary

This section lists the applications of AI-based intelligent equipment and systems during the pandemic (Table 2). This table contains the type of adopted equipment and systems, contributions of the citation paper, and the author and year information of publications. As Table 2 shows that, which concludes the intelligent equipment and systems applications excluding potential virus carriers, telemedicine service, and economic recovery. As the table shows, recent researchers developed diverse types of intelligence equipment and systems in convergence with AI technology to contain the spread of the pandemic. Undoubtedly, AI has demonstrated strong inclusivity, which could conveniently integrate into various equipment and systems, such as helmets developed by Mohammed et al. (2020), sensors researched by Medgadget (2020), and telemedicine systems proposed by Bhaskar et al. (2020).

4. Intelligence robots with AI

The intelligent robot with AI integrates ancillary machinery, equipment, and devices with the advanced controller (Hunt, 1985). Compared with intelligent devices and systems, AI-based intelligent robots have significantly advanced multi-modal perception (Sundaram, 2020), active learning (Taylor et al., 2021), human–computer interaction capabilities (Saunderson and Nejat, 2021). And with the advancement of AI, robots, such as social robots used for teaching (Belpaeme et al., 2018) and space robots used for space exploration (Gao and Chien, 2017), can replace manual for highly repetitive and risky tasks, which have become increasingly important in our lives. In addition, intelligent robots

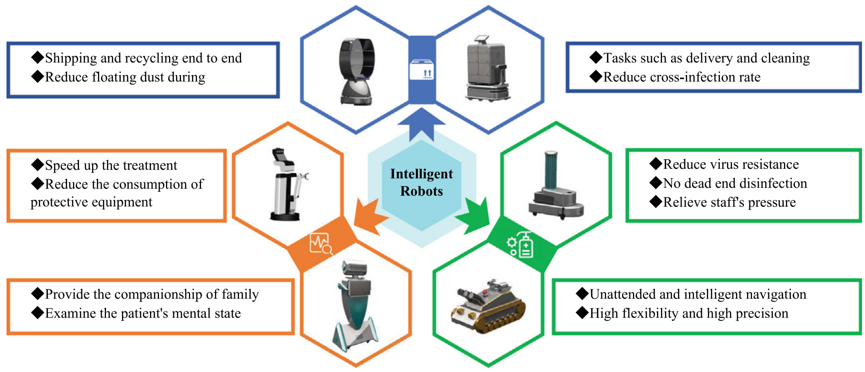

Fig. 4. AI-based intelligent robots fight the pandemic.

have made contributions to the challenges uncovered in COVID-19 pandemic prevention and control processes, such as medical distribution, disinfection tasks, and health care. To this purpose, Yang et al. (2020) focused on analyzing intelligent robots' feasibility in fighting against the pandemic, and the process also could promote the development of robotics technology. The successful application of intelligent robots exemplifies the importance of AI in combatting the pandemic. As Fig. 4 shows, the various categories of robots were exclusively developed for the pandemic, including intelligent distribution, disinfection robots so on. This figure has listed six typical robots and provided their function descriptions. Notably, intelligent robots are widely deployed in pandemics in that they can replace humans in repetitive tasks and block the propagation of viruses at the physical spatial. This section mainly reviewed and discussed the application of intelligent robots in the pandemic.

4.1. Material distribution

During a pandemic, intelligent handling robots can replace manual handling and distribution, improving material supply efficiency and lowering the risk of staff cross-infection. In the hospital situation, these principles apply particularly for the huge hospitals erected during China's pandemic, such as Huoshenshan and Leishenshan. There is a significant amount of manual handling of medical supplies; hence, intelligent handling robots are extremely necessary. Intelligent handling robots include medical equipment handling robots, drug handling robots, garbage recycling robots, and handling robots. Intelligent robots can transfer and recycle medical equipment from the warehouse to the operating room, move medical supplies from the warehouse to the ward and distribute drugs from the pharmacy to the ward. It can also reduce the creation of floating dust during the handling process, which is critical in sterile operating rooms and isolation units. Takahashi et al. (2010) developed an autonomous omnidirectional mobile distribution robot system for hospitals, transporting luggage, essential specimens, and other materials. Aiming at the limitation that a single delivery robot can only complete one task at a time, Jeon et al. (2017) proposed a fleet optimization method by assigning multiple tasks to one robot to maximize the simultaneous operation of a group of robots. They also proposed an algorithm to reduce the amount of calculation of the search path combination to improve multirobot collaborative work efficiency.

Taking suitable isolation procedures is critical to halting the infectious process. It usually entails quarantines at home as well as the establishment of quarantine zones. Whatever isolation procedure is used, there is an inescapable difficulty with the material supply in the isolation area. In this situation, some supermarkets and restaurants can deploy several delivery and handling robots to create an intelligent unattended environment that autonomously entertains clients, delivers meals, cleans tables, and does other chores to prevent consumer cross-infection (Huang and Lu, 2017; Antony and Sivraj, 2018). Yuan et al. (2019) designed an express vehicle platform based on a hub motor drive. It can realize autonomous delivery tasks in complex terrain through an intelligent delivery robot that combines AI technology with a handling robot. In this way, on the one hand, the size of the distribution box can be adjusted according to the size of the package; on the other hand, the separation of the car cabinet can be realized, and the whole container can be directly replaced, which provides technical support for the material distribution robot to achieve the community downstairs distribution task. During China's fight against the pandemic, the intelligent distribution robot independently developed by Jingdong logistics was quickly put into application and realized the initial supply of materials to Wuhan.

4.2. Disinfection

COVID-19 spreads through droplets and contaminated surfaces and can persist for several days on surfaces devoid of vital signs, such as metal, glass, and plastic. In the process of preventing the spread of the pandemic, the most critical link is conducting all-around disinfection without dead ends in multiple scenarios. And, different scenarios have different sterility requirements, and the required disinfection strength also differs. Intelligent Robots are recommended to perform cleaning tasks to avoid human-to-human contact.

The hydrogen peroxide vapor (HPV) disinfection robot employs gaseous hydrogen peroxide, and Its action principle is to dissociate and attack the hydroxyl groups of viruses with high activity through complex chemical reactions and then destroy the cell membrane, protein, and DNA of the virus to achieve disinfection and sterilization. Such robots are usually used to sterilize enclosed spaces, such as isolation wards and operating rooms. HPV can help to reduce pollution and the danger of generating drug-resistant organisms (Passaretti et al., 2013). However, a HPV disinfection robot is only beneficial in the visible region. Such robots cannot reach enclosed areas, such as drawers containing items or drawers' bottom (Okkesim and Manav, 2015). By releasing a specific wavelength of ultraviolet light, ultraviolet disinfection (UVD) robots disrupt the molecular structure of deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) in microorganism cells, causing the permanent death of growing cells and regenerative cells to achieve sterilization. Guettari et al. (2021) developed a AI-based robot called I-Robot UVC, which can kill 99,999% bacteria and various through UVC lamps led. And, ultraviolet devices are excellent in reducing pollution on hospital high-contact surfaces (Yang et al., 2020).

During the pandemic, Ramalingam et al. (2020) proposed an AI-enabled framework for automating door handles cleaning tasks through a Human Support Robot (HSR). Specifically, they exploited a CNN-based deep learning method to classify the image space and provide a set of coordinates for the robot. Hong et al. (2021) developed an AI-based UVD robot capable of recognizing objects and locations with a high probability of contamination and capable of providing quantified sterilization effects. Besides, to improve the disinfection efficiency of UVD robots, Hu et al. (2020c) developed a U-Net model to segment and map areas of potential contamination in three dimensions based on the object affordance concept. In addition, Le et al. (2021) presented a human safe distance monitoring technique using Toyota HSR and AI-assisted 3D computer vision framework, which can decrease about 19% of the disinfection time and 15% of the liquid usage. Using AI-based detection and recognition algorithms can effectively improve the disinfection process of robots.

Most of the existing disinfection robots integrated the Automatic Guided Vehicle and the disinfection device. In fact, for remote areas and those with complex terrains, such disinfection robots cannot perform well. Harfina et al. (2021) designed a unmanned aerial vehicle (UAV) quadcopter using a 2200 kV BLDC motor controlled by the SP Racing F3 flight controller, and which can carry 200 ml of sprayed disinfectant. These UAVs can be easily operated and mobilized and keep the operator away from getting infected, because there may be chances that sanitization workers may be exposed to viral infections while discharging their essential duties (Devi et al., 2021). Furthermore, in response to the lack of adequate medical facilities and medical staff in remote areas, Naren et al. (2021) proposed an IoMT and DNN-enabled drone framework, which can use for contactless COVID-19 diagnosis, testing, and disinfection in real life. To this end, combined with AI technology, robots have more outstanding capabilities and performance.

4.3. Health care

During the pandemic, a significant number of patients put much strain on local hospitals, and a lack of medical personnel has become a major obstacle in the prevention and control process. Furthermore, to protect medical staff from a viral infection, they must wear heavy protective clothing and undertake deep disinfection work when interacting with patients, making it impossible for them to function efficiently for an extended period. To address the aforementioned issues, intelligent robots are used in the health care process to assist medical professionals in completing their daily activities. Tabaza et al. (2021) described the case of a patient with suspected COVID-19 who required urgent coronary artery interrogation, in which they used robotic assistance to reduce the risk of COVID-19 exposure while also reducing the amount of personal protective equipment required by the procedure team.

Currently, nucleic acid testing is a significant method for detecting individuals with COVID-19, and the detection process often necessitates the patient's nasopharyngeal swab collection. Since this process is tedious and repetitive, the deployment of intelligent robots to lessen the strain on medical staff can surely speed up the detection process (Yang et al., 2020). Wang et al. (2020c) proposed a low-cost, easy-to-assemble, and remotely operated microrobot to perform nasopharyngeal swab sampling efficiently. To perform swab tests on patients, Li et al. (2020a) created a semi-automatic oropharyngeal swab robot. The swab robot is outfitted with a remote camera, allowing medical personnel to sample with clear eyesight without making direct contact with the patient, and the sampling success rate has reached 95%. The results show that the sampling process of the intelligent oropharyngeal-swab robot is safe, with a high success rate of sampling. During the pandemic, a significant number of confirmed patients will put more surgical burden on doctors, and robot-assisted doctors in surgery will be extremely important. Kanade and Kanade (2020) proposed a robot arm operated by a smartphone's Bluetooth to assist medical staff in treating COVID-19 patients and providing patients with drink, food, and medicine. However, the proposed robotic arm was only developed in the lab and has yet to be evaluated in the real world. In practice, a great deal of verification is required prior to actual application and production. Van den Eynde et al. (2020) discussed the potential risks, benefits, and preventive measures that need to be taken into account when considering robotic surgery for cardiothoracic indications in patients with confirmed COVID-19. According to the findings, robot-assisted surgery has the advantages of early postoperative recovery, short hospital stay, less blood and fluid loss, and minimal incisions. However, there is a possibility that virus particles will be atomizing during this procedure.

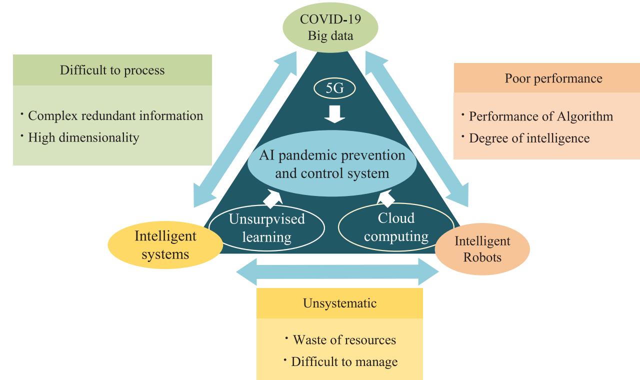

Fig. 5. Emergency prevention and control system based on AI.

At the same time, a pandemic will increase psychological stress on individuals, and mental health is a vital factor that cannot be overlooked. For that purpose, Ouerhani et al. (2020) created COVID-Chatbot, an intelligent omnipresent chatbot that is used to provide COVID-19 help during and after isolation, as well as engage with residents to comprehend the individual's mental state. The technique consists of four interconnected modules: the information understanding module (IUM), the data collector module (DCM), the action generator module (AGM), and the depression detector model (DDM). This technique uses IUM to process natural language and DCM to collect nonconfidential information from the user. Later, DDM completes sentiment analysis to assist AGM in making a decision, and ultimately, AGM generates the chat robot's response. After tracing and evaluating the 195 experiences of 66 different social robots from around the world, Aymerich-Franch and Ferrer (2020) discovered that the robot can work as a health coach, providing therapeutic and entertaining services for quarantined patients. To that end, AI-based robots can play a significant role in reducing the transmission of infectious diseases and delivering high-quality care for patients, including diagnosis and treatment in a hospital setting, as well as home care following rehabilitation.

4.4. Application summary

This section lists the applications of AI-based robots during the pandemic. Table 3 concludes the intelligent robots in distribution, disinfection, and health care tasks. The AI-based UVD robot proposed by Yang et al. (2020) can not only recognize object locations with a high probability of contamination and provide quantified sterilization effects. It is not difficult to find that robots incorporated with AI have more powerful performance and functions.

5. Discussion

As mentioned in Sections 2–4, AI in conjunction with COVID-19 big data, intelligent devices and systems, and intelligent robot technologies has played an essential part in combatting the pandemic. As Fig. 5 presents, the following challenges were faced in the fight against the pandemic: (1) COVID-19 data are multidimensional and difficult to process, (2) the algorithm is not particularly intelligent, and (3) the process of prevention and control is not systematic. This Figure shows that the new technologies, like 5G, unsupervised learning, and cloud computing could pay more activity to AI-based pandemic prevention and control systems. This section goes over the challenges and solutions described above.

(1) COVID-19 big data from multiple sources have complex redundant information, high dimensionality, and complex processing.

Table 3
The application summaries of intelligent robots during the pandemic.

R	Applications	Techniques	Key Contribution	Ref
1	Distribution	Autonomous omnidirectional mobile distribution robot	Transporting luggage, essential specimens, and other materials for hospital.	Takahashi et al. (2010)
2	Distribution	Multi-robots, fleet optimization.	Multi-robots work together efficiently.	Jeon et al. (2017)
3	Distribution	Intelligent delivery robot combines AI.	Autonomous delivery in complex terrain.	Yuan et al. (2019)
4	Disinfection	I-Robot UVC.	Kill 99, 999% bacteria and various through UVC lamps led.	Guettari et al. (2021)
5	Disinfection	Toyota HSR, CNN.	Identify high contamination probability locations and provide quantified germicidal effects.	Yang et al. (2020)
6	Disinfection	AI-based UVD robot.	Recognizing object locations with a high probability of contamination and providing quantified sterilization effects.	Hong et al. (2021)
7	Disinfection	Toyota HSR, AI-assisted 3D computer vision framework.	Decrease about 19% of the disinfection time and 15% of the liquid usage.	Le et al. (2021)
8	Disinfection	UAV.	Disinfection in remote areas and complex terrain fields.	Harfina et al. (2021)
9	Health care	Microrobot.	Remotely operated to perform nasopharyngeal swab sampling.	Wang et al. (2020c)
10	Health care	Semi-automatic oropharyngeal swab robot.	The sampling success rate has reached 95%.	Li et al. (2020a)
11	Health care	Robot arm operated by a smartphones Bluetooth.	Providing patients with drink, food, and medicine.	Kanade and Kanade (2020)
12	Health care	COVID-Chatbot.	Comprehend the individuals mental state.	Ouerhani et al. (2020)

Although big data analysis and processing can accurately anticipate pandemic information using AI algorithms, multi-sensor fusion introduces considerable redundant information, which can easily lead to an explosion of information dimensions and, as a result, challenging processing of multisource big data. Furthermore, under physical conditions, the core computing chip is constrained by the process, limiting its processing capacity. These factors have an indirect impact on the AI algorithm's performance and forecast accuracy.

In recent years, 5G communication technology has matured, and its low latency and low packet loss rate can provide technical support for cloud computing (Andrews et al., 2014). Cloud computing, as a novel computing approach, primarily refers to the storage, processing, and analysis of data via cloud servers. Real-time data transmission using 5G communication technologies can overcome the limitations of core chip processing capabilities (Varghese and Buyya, 2018). With its excellent characteristics, cloud computing has been applied in a variety of fields, such as genome data processing and collaboration (Langmead and Nellore, 2018). Big data processing and analysis via cloud computing, 5G technology, and AI algorithms is a reliable measure for pandemic prevention and control, such as when (Tuli et al., 2020) reasonably predicted the growth trend of COVID-19 through machine learning and cloud computing. Using cloud computing to process and analyze big data is an important research direction in the future.

(2) The intelligence of algorithms and their performance must be improved. Although the deep learning algorithm outperforms the others in many ways, it is limited not only by the dataset and computational capability but also by the algorithm itself. The supervised learning algorithm is currently more widely used. As a result, a significant amount of manpower and material resources are required to prepare the dataset in the early stages, and the algorithm's performance has reached a bottleneck that must be addressed. As the intelligence of multi-intelligence systems and intelligent robots increases, less human engagement is required, and the pandemic prevention and control impact improves.

In recent years, unsupervised learning in deep learning algorithms has become increasingly popular among scholars. Research on new algorithms such as unsupervised learning is significant in improving algorithm performance and intelligence degree (Shrestha and Mahmood, 2019). To achieve a breakthrough in AI, it is necessary to carry out corresponding research on unsupervised learning. At the same time, unsupervised learning in pandemic prevention and control is more suitable for various complex and changeable scenarios.

(3) The prevention and control system has not been systematic. Although AI fights the pandemic by processing COVID-19 big data, intelligent equipment and systems, and intelligent robots, there is no systematic plan to coordinate the prevention and control system. On the one hand, it may cause a waste of resources, such as multiple disinfections of a scene and the existence of disinfection at a dead angle; on the other hand, it is not conducive to the management and operation of intelligent robots or an individual intelligent system. Therefore, the formation of an AI pandemic prevention and control system is significant to preventing and fighting against the pandemic.

First, it needs to build a big data cloud platform for the multisource data collected by the intelligent equipment and system's multi-smart systems, such as smart medical care and smart transportation, and unify data information management through the big data platform. The pandemic prevention and control robots and intelligent equipment and systems are then connected to an AI pandemic prevention and control system through the 5G network to realize the real-time monitoring of each person's physical information. Medical staff can track the physical condition of each patient in real time through terminal equipment. Abnormal body temperature can give feedback to the terminal in real time and send the signal alarm. Finally, the formation of this AI pandemic prevention and control system can not only be used for the prevention and control of the pandemic but also have a particular preventive effect on the occurrence of other significant emergencies, such as earthquakes. Moreover, this system's construction can also promote the development of a variety of cutting-edge technologies, such as intelligent robots, intelligent transportation, smart medical care, and cloud computing, which is significant to promote human progress.

6. Conclusion

In today's digital world, AI is more than simply a notion that mimics human behavior and reasoning; AI may also be a useful weapon in the fight against disasters, such as COVID-19. From the perspectives of COVID-19 big data, intelligent equipment and systems, and intelligent robots, this paper performs deep research of the application of AI technology in the pandemic. AI can anticipate and track the spread of a virus in the early stages of the pandemic when the virus is spreading on a small scale using big data from the pandemic, which can considerably assist government agencies in adopting timely preventative and control measures. With the widespread of a virus, AI can help researchers produce vaccines faster by replacing clinicians in diagnosis and treatment based on big data. Staff can swiftly identify virus carriers using AI smart devices and systems. Material handling and distribution, disinfection, and patient care can all be completed by robots using AI. With the advancement of 5G, cloud computing, and other technology in the future, AI may be capable of playing a crucial component in responding to other major disasters.

CRediT authorship contribution statement

Junfei Yi: Writing – original draft, Writing – review & editing. **Hui Zhang:** Conceptualization. **Jianxu Mao:** Supervision. **Yurong Chen:** Investigation. **Hang Zhong:** Project administration. **Yaonan Wang:** Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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