ORIGINAL PAPER

Convergence model of AI and IoT for virus disease control system

Sungho Sim [1] · Myeongyun Cho [2]

Abstract

Recently, virus diseases, such as SARS-CoV, MERS-CoV, and COVID-19, continue to emerge and pose a severe public health problem. These diseases threaten the lives of many people and cause serious social and economic losses. Recent developments in information technology (IT) and connectivity have led to the emergence of Internet of Things (IoT) and Artificial Intelligence (AI) applications in many industries. These industries, where IoT and AI together are making significant impacts, are the healthcare and the diagnosis department. In addition, by actively communicating with smart devices and various biometric sensors, it is expanding its application fields to telemedicine, healthcare, and disease prevention. Even though existing IoT and AI technologies can enhance disease detection, monitoring, and quarantine, their impact is very limited because they are not integrated or applied rapidly to the emergence of a sudden epidemic. Especially in the situation where infectious diseases are rapidly spreading, the conventional methods fail to prevent large-scale infections and block global spreads through prediction, resulting in great loss of lives. Therefore, in this paper, various sources of infection information with local limitations are collected through virus disease information collector, and AI analysis and severity matching are performed through AI broker. Finally, through the Integrated Disease Control Center, risk alerts are issued, proliferation block letters are sent, and post-response services are provided quickly. Suppose we further develop the proposed integrated virus disease control model. In that case, it will be possible to proactively detect and warn of risk factors in response to infectious diseases that are rapidly spreading worldwide and strengthen measures to prevent spreading of infection in no time.

1 Introduction

Recently, infectious virus diseases, such as SARS-CoV, MERS-CoV, and COVID-19, continue to emerge and pose a severe public health problem[1–3]. First, SARS-CoV is said to have started in 2003 when a new coronavirus was infected with humans from bats in China's Guangdong Province market. A total of 8096 cases in 29 countries worldwide reported 774 deaths, resulting in a fatality rate of 9.6%[1]. Second, MERS-CoV began in 2013 in Saudi Arabia after being infected with humans through bats and camels. The disease caused 2494 confirmed cases and 858 deaths in 27 countries[2]. Most recently, the new COVID-19, which occurred worldwide in Wuhan, Hubei province, China in December 2019, has increased to 6.11%, with 6,008,000 confirmed cases and 370,000 deaths as of May 2020[3]. SARS, MERS, and COVID-19 all have symptoms in common, such as fever and cough, and have the commonality that the spread between humans spreads rapidly through the respiratory system. The disease, which is still ongoing, is not only threatening many lives, but it is also causing serious social and economic damages[4].

Currently, various technological approaches have emerged to combat viral epidemics. Among them, digital technologies including next-generation communication networks such as IoT, Wearables, and AI are representative[5, 6]. The Internet of Medical Things (IoMT), also known as healthcare IoT, introduced the integration of biometric devices and software applications that provide healthcare services[7, 8]. At this time, the number of application programs increased rapidly

✉ Myeongyun Cho
  mg_cho@semyung.ac.kr

  Sungho Sim
  shshim@semyung.ac.kr

1 College of General Education, Semyung University, Jecheon, Korea

2 School of Information and Communication Systems, Semyung University, Jecheon, Korea

with the installation of NFC (Near Field Communication), which allows more mobile devices to interact with the IT system[9, 10]. Typical biometric devices are smart thermometers[11] that measure and report the user's body temperature, IoT buttons[12] to warn of hygiene problems in hospitals, and bio-sensor patch [13] to support remote patient monitoring.

Wearable refers to a device worn on the body having a function of connecting to the Internet. The wearable device has been adopted as an ideal means in the healthcare field due to its excellent ability to monitor the user's stress level and physical fitness [14]. These include a smart watch[15] that periodically sends biometric information to the manager, a Bluetooth location beacons[16] that tracks the user's location and contact, and a telemedicine[17, 18] that allows clinicians to evaluate patient remotely. This wearable is characterized by being connected to an individual smartphone and periodically transmitting data by accessing the Internet. Artificial intelligence(AI) has been recognized as a breakthrough in 2000 since its inception in 1956, and if used correctly, it can be a very effective tool against various viral epidemics[19]. If we list effective ways for AI to combat epidemics, there are disease monitoring[20] and risk prediction[21], medical diagnosis and screening[22], treatment research[23], virus modeling and analysis [24], lockdown measures trial[25]. Using this AI method can serve to alleviate the effects of viral infections.

Although existing IoT and AI technologies can enhance disease detection, monitoring, and quarantine, their impact on infection control is very limited because they cannot be rapidly applied to the outbreak of an epidemic. In particular, in a situation where epidemics spread rapidly across countries, existing methods with regional restrictions do not prevent large-scale infections and prevent global spread through rapid prediction, resulting in large-scale loss of lives. Therefore, in this paper, we have defined a unit that responds to the spread of serious viral diseases as not one country but global and proposed an integrated disease control system that oversees detection, analysis, and response. In the virus disease information collection stage, IoT devices signal, disease network monitoring, and published disease prevention information are collected, and then AI Broker performs virus disease classification matching and AI analysis based on the collected information. Finally, the disease control center will provide the most reasonable service to the user.

In the "Related works" section, the existing research on IoT, wearable device, AI for viral disease prevention is arranged, and the limitations of previous studies were analyzed. We suggested the integrated virus disease control system using IoT and AI convergence and explained the operating principles of the proposed system in the "Convergence model" section. In the "Simulations or evaluation" section, the suggested disease control model's advantage and efficiency are compared and analyzed with the existing disease prevention system using IoT, Telemedicine, and AI techniques, respectively. Finally, in the "Conclusions" section, the suggested system's general conclusion will be made, and the future development direction will be discussed.

2 Related works

2.1 Biometric information collection system using IoT

IoMT (Internet of Medical Things), called healthcare IoT, provides powerful healthcare services by connecting a biometric sensor measurement device and a software applications[5, 6]. As shown in Fig. 1, IoMT, like the IoT, has seen a rapid increase in the number of potential applications. This surge is due to the fact that more and more mobile devices are now equipped with Near Field Communication (NFC) module that allows these devices to interact with IT systems[7, 8].

IoMT applications include:

1) Monitoring the patient from a remote location
2) Tracking medication prescriptions
3) Biometric sensors are used to transmit health information to related medical experts.

The ability to efficiently collect, analyze and transmit biometric data has made the healthcare application realize the innovative potential of IoMT technology[9, 10]. The following is a list of effective IoMT techniques for monitoring the effects of infectious diseases and managing the results.

– Smart thermometer[11]

US healthcare company named Kinsa launched an internet-connected thermometer to screen people with high fever. The thermometer was developed to track the common flu, but it can be connected to a mobile application and immediately send body temperature information from all over the USA to relevant agencies. This allows US authorities to monitor areas of high fever populations to identify potential viral infection hotspots.

Fig 1 IoMT (Internet of Medical Things)

– IoT buttons[12]

It was established to maintain high hygiene standards for hospitals in Canada and to limit the number of hospital-acquired infections. It is designed to promptly alert the surroundings to minimize the risk to public safety in the event of a hospital infection.

– Biosensor patch[13]

It is the biosensor patch put on one's chest. Disposable, showerable, and lightweight wearable biosensor patch fixed to the chest area can record a person's temperature along with breathing rate, ECG tracking, and heart rate. The data is automatically sent from the user's patch to his smartphone, enabling them to view data in real time.

2.2 Telemedicine system using various wearables

Wearable refers to a device worn on the body having a function to connect to the Internet. The wearable device has been adopted as an ideal means in the healthcare field due to its excellent ability to monitor the user's stress level and physical fitness[14]. The representative devices are as follows.

– Smart watch[15]

Smart watch that periodically sends biometric information such as body temperature and pulse rate to the center.

– Workplace level contact tracing wearable[16]

Location tracking device of user and contactor using Bluetooth and beacons

– Telemedicine[17, 18]

The practice of using wearables to facilitate remote patient monitoring is called telemedicine. This practice, also called remote healthcare, allows clinicians to evaluate, diagnose, and treat patients without physical interaction with them. Figure 2 shows architectural elements of wearable IoT for telemedicine. Several IoMT technologies and telemedicine platforms with wearables have skyrocketed after the emergence of the highly contagious coronavirus.

2.3 Image signal processing and virus infection detection using AI

Artificial intelligence has been recognized as a groundbreaking technology since the introduction of ML in the 2000s, since research began in 1956. Proper use of AI can be a very effective tool against a variety of viral infections[19]. When we lists actual and potential ways for AI to combat the epidemic, disease surveillance[20], risk prediction[21], medical diagnosis and screening[22], curative studies[23], virus modeling and analysis[24], and implementation of lockdown measures[25], which are shown in Fig. 3.

-Disease Surveillance[20]

Timely monitoring and prediction of diseases, especially those that can disrupt the world, are very important. Health monitoring company BlueDot has successfully reported to the WHO that the coronavirus is imminent at the end of December 2019. Their BlueDot model used machine learning (ML) and natural language processing (NLP) to find evidence of new diseases and predicted the second SARS-CoV before epidemiologists. The large amount of data collected about viruses was used to predict the viruses that could cause the greatest damage to human species by forming AI and technology.

-Risk Prediction[21]

Another way to apply AI to coronaviruses is risk prediction. In general, the risk of infection is determined by a number of factors. This includes age, travel history, hygiene habits, current health status, existing health status, and family history. Therefore, by introducing the degree of vulnerability to the new virus (vulnerability index), we can extract a ML (machine learning)-based strategy. These preemptive knowledge of viruses has made doctors and healthcare providers better prepared for the threats they face.

-Medical Diagnosis and Screening[22]

Through the rapid diagnosis of viral infections, the government can take effective countermeasures to prevent the spread of the disease. However, the lack of diagnostic kits worldwide has made it difficult for authorities to conduct large-scale diagnostic tests. To solve this problem, AI is innovating the screening and diagnostic process by applying various methods. First, IR-based body temperature measurement is performed through an AI-based multisensory technology-applied camera, and when an infected person occurs, people around him can be found through facial recognition. In addition, AI technology performs CT scan and X-ray analysis through image-based medical diagnosis.

-Curative Research[23]

Several research institutes are using AI to derive potential treatments for new coronavirus and conducting research to accelerate the development of new drugs by analyzing the application of existing drugs.

-Virus Modeling and Analysis[24]

Understanding the virus itself is key to developing successful treatments for viral infections. Virus typically infects a host cell by binding itself to the host's receptors via a lock and key mechanism. The working mechanism for most inhibitor-based agents is to prevent this from happening by blocking the receptors of the target cells. Therefore, for the design of effective inhibitors, the ML technique of AI is one of the most useful tools.
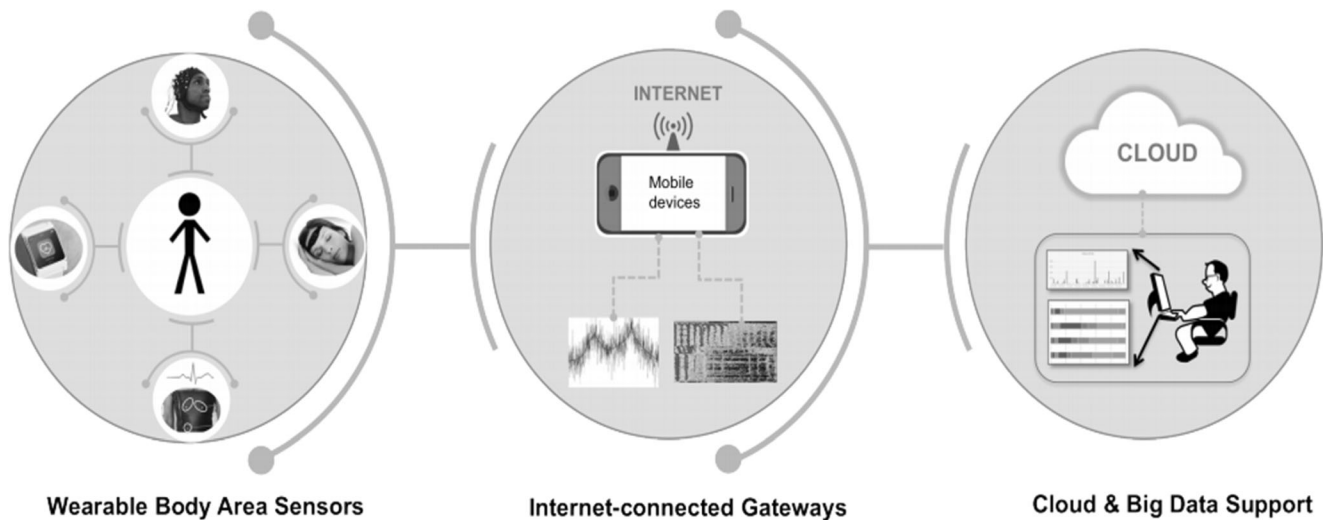
-Management of Lockdown Measure[25]

Fig 2 Architectural elements of wearable IoT for telemedicine[14]

Many countries around the world are using AI to enforce social distance and containment measures. In China, Baidu, one of the largest AI and internet companies in the world, has developed computer vision (CV) powered infrared cameras to scan public places. These cameras can not only identify people with high body temperatures, but via the use of their inbuilt facial recognition system, they can also recognize citizens who are not following the lockdown measures.

2.4 Limitations of existing virus infection prevention methods

For the existing infection prevention technology, IoMT, wearable device, and AI field technologies were applied independently to propose a diagnosis or response system for viral infections. However, by applying the proposed technology only locally, it was difficult to respond quickly to the rapid spread of disease in a world where there is a frequent movement worldwide.

Although it is possible to enhance disease detection, monitoring, and quarantine through existing IoT and AI technologies, it can be applied only after the epidemic has spread, so its efficiency in terms of prevention is limited. In particular, in a situation where epidemics spread rapidly across countries, large-scale loss of life was inevitable because the existing methods did not predict and prevent large-scale infections in advance and cannot prevent the spread among countries due to the absence of a global integrated system.

Therefore, in this paper, we focus on the commonalities of viral infections transmitted to the respiratory tract, and warn before infectious diseases develop in earnest, and restrict the movement of infected people to prevent spread to other areas. In addition, by suggesting an integrated virus infection control system, it is possible to perform post-quarantine control.

3 Convergence model for virus disease control system

The convergence model for virus disease control system defines the concept of virus disease as a premise of spreading across countries, rather than as problem of a single nation, and seeks to approach from the general model of detection and response to virus disease. The damage caused by virus disease to countries is increasing rapidly, and it is difficult to deal with the initial response and effective prevention response through

Fig. 3 Applications of AI for virus disease impact management[19]
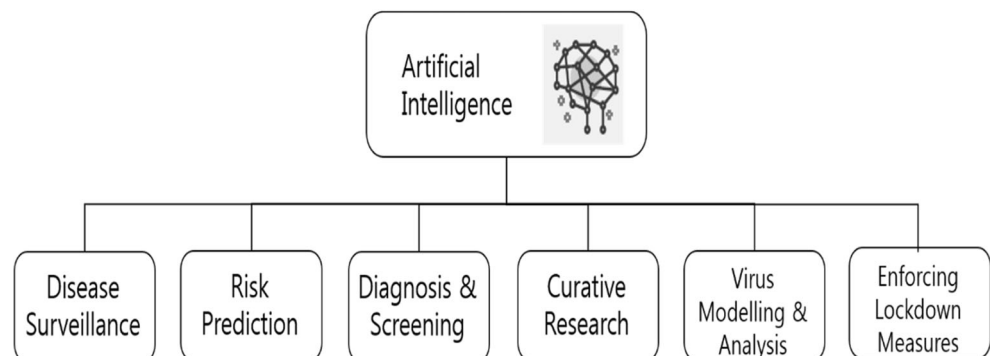
the spread among countries. Therefore, a virus disease control system that can detect virus disease and apply an early response system is required. This section proposes a virus disease control system by applying an AI and IoT convergence model. Figure 4 shows the structure of the virus disease control system.

3.1 Virus disease analysis technical components

The virus disease control system using artificial intelligence and IoT convergence model is based on the technical elements and artificial intelligence elements applied in IoT. The virus disease control system has five components: virus disease data collection, virus disease data processing, and abbreviation, AI analysis, service matching by classification, and prevention matching service support. The data collection step collects information related to virus disease and data from IoT devices. The collected test data is transformed into meaningful information to enable virus disease determination at the data processing and abbreviation step.

As a core step of the proposed system, artificial intelligence analysis is divided into IoT matching technique and artificial intelligence analysis technique based on information collected. The IoT matching technique performs matching of virus disease classification data and collected information. The artificial intelligence analysis technique generates information about new virus diseases through analysis of collected data.

Service matching by classification provides service information by classification based on analysis and matching results. Service matching by classification provides service information by classification based on analysis and matching results. Prevention matching service support is a differential response process based on virus disease analysis, and appropriate prevention and follow-up measures are taken at the virus disease control center. Figure 5 shows the technical components of the virus disease control system.

3.2 Control system of virus disease applying fusion model

The virus disease control system using the convergence model is constructed based on the results of matching and AI analysis based on IoT environment collection data and agent monitoring information. The proposed system consists of a virus disease information collector, a disease information repository, and an AI broker. Based on the analysis and matching information, the central control center receives appropriate disease services. The proposed system aims to provide early response and appropriate service for effective virus disease control by reflecting the technical components of the collection and analysis technique in the event of virus disease outbreak. Figure 6 shows the system proposed in this paper.

Service requesters can request individual disease information from the disease data repository. The virus disease
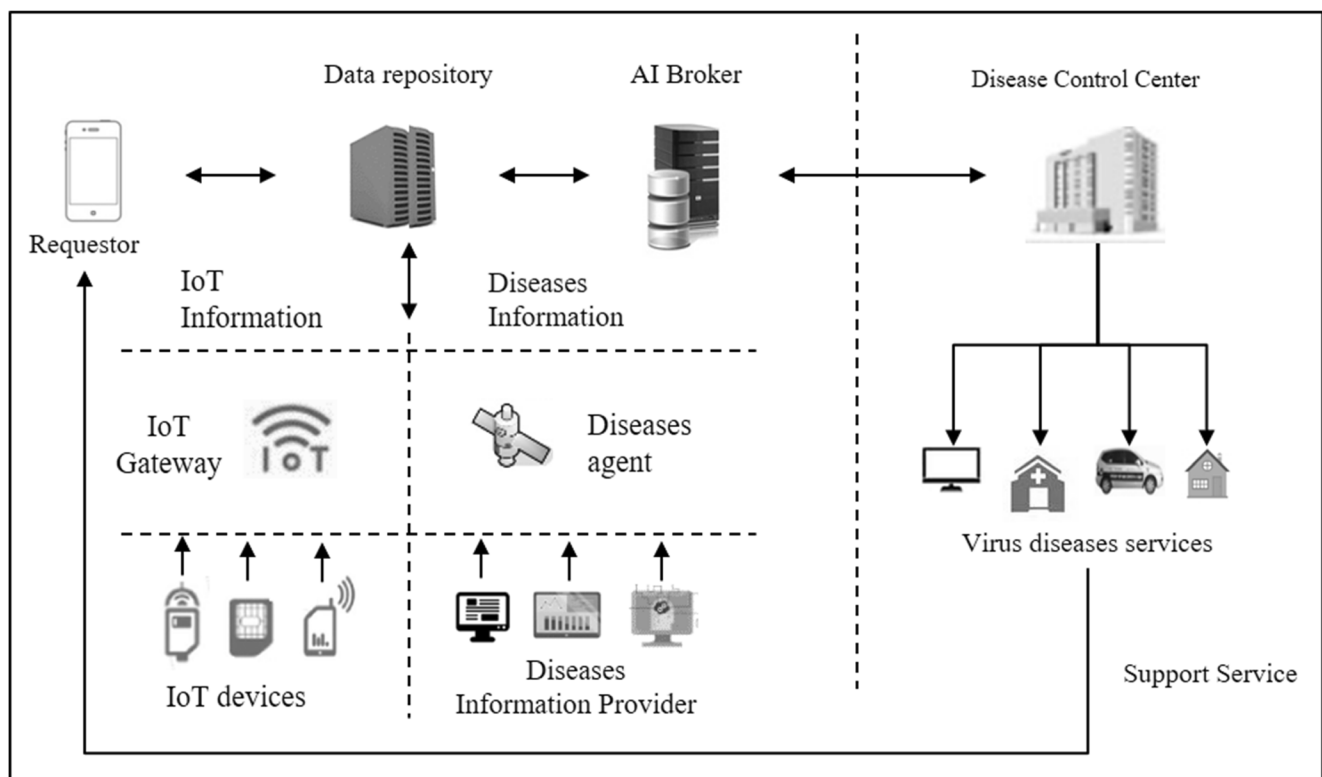
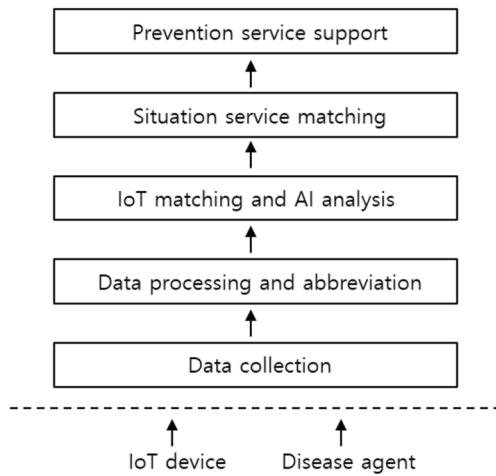**Fig. 4** Virus disease control system structure

Fig. 5 Information collection and analysis technology components

information collector collects IoT device information and collects virus diseases information from the disease management server using the disease agent. AI broker performs virus disease classification matching and AI analysis based on the collected information. Based on the results, service information for each classification is provided, and classification information for serious stages is provided to a central control center. The central control center uses the information provided to support virus diseases service for each situation.

3.3 Virus disease information collection

The virus disease information collection step collects virus infection stage information using disease network monitoring,

collects suspicious virus infection information using IoT devices, and collects disease outbreak information provided by disease management centers and health organizations Virus infection stage information collection using agent monitoring is used to collect the initial information on virus disease occurrence and determine the region, range, and transmission speed. Virus infection suspicion information collection using IoT devices is used to apply foreign virus blocking and early prevention systems through the construction of IoT environments in immigration areas. Disease outbreak information collection is used for information on epidemic virus diseases, regional virus information, and to register information about new viruses. Figure 7 shows the virus disease information collector.

IoT device information, monitoring agent information, and disease outbreak information collected from the virus disease information collector are stored in a data repository and provided to AI broker. The collected information is filtered for disease information so that it can be applied to the disease classification system.

3.4 AI broker

The AI broker performs matching and AI analysis based on information collected through the repository's IoT device information and disease agent monitoring. In disease information filtering, virus disease data is extracted, and matching information and analysis information are generated. The generated information is provided to the matchmaker and AI analysis module. Matchmaker matches the processed information
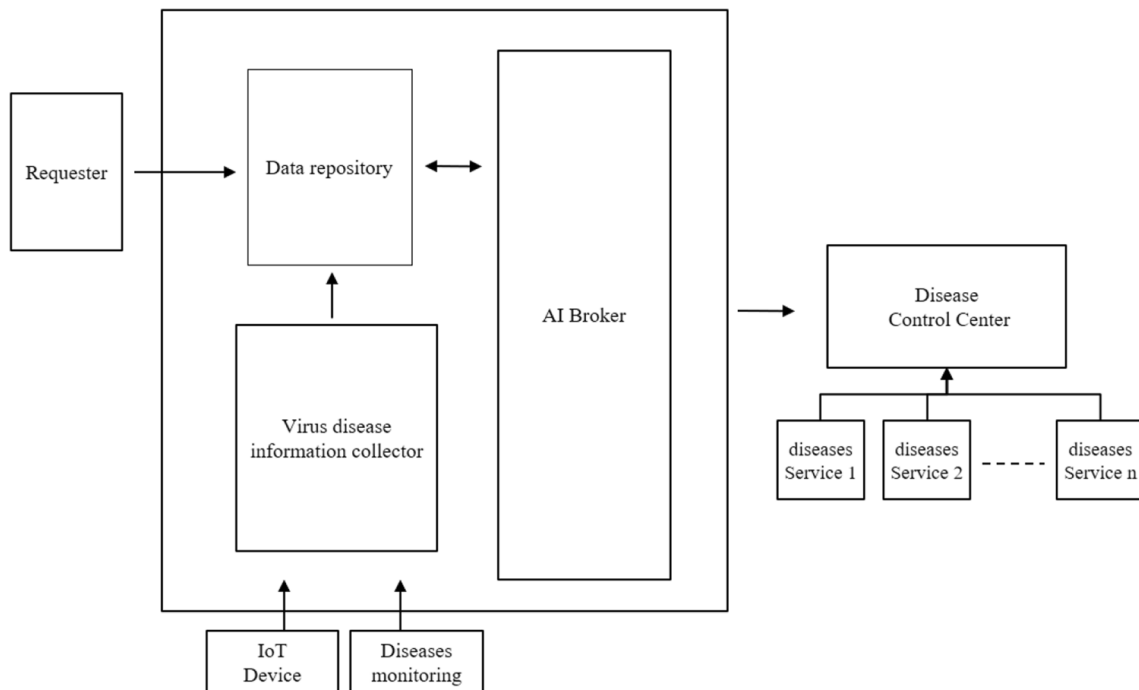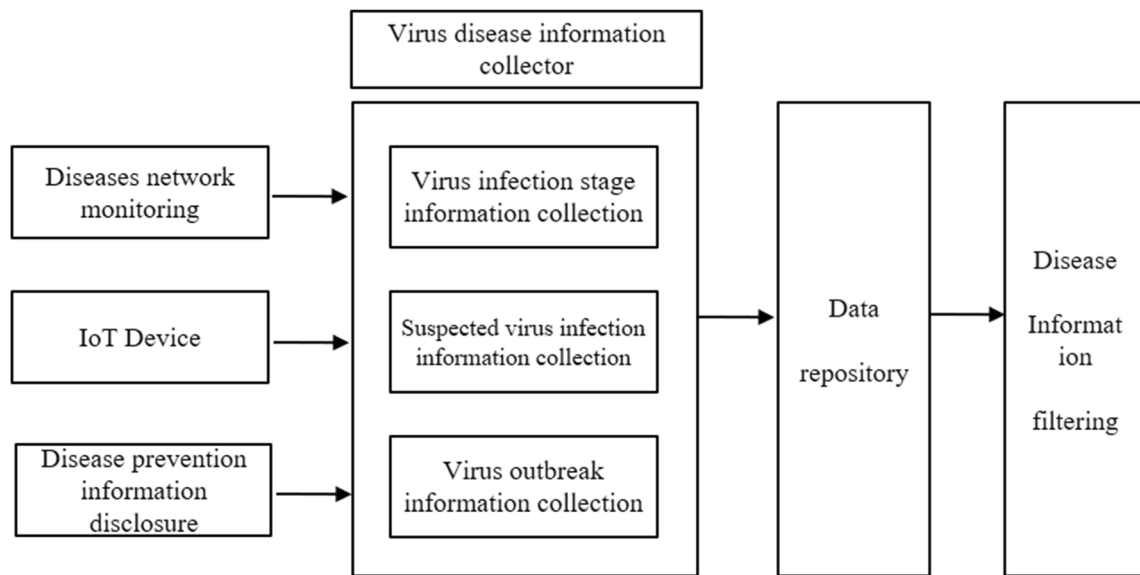

Fig. 6 Proposal system

Fig. 7 Virus disease information collector

with the criteria in the disease classification system. The infectious disease classification system performs matching tasks related to a total of 86 infectious diseases of Level 1 to Level 4. After matching by classification, if a first-rank symptom or mismatching with infectious disease classification system occurs, the corresponding information is provided to the AI analysis module. Figure 8 shows the AI broker.

Virus disease suspicion information is detected through AI analysis module through static analysis and dynamic analysis. Static analysis detects a variant virus disease by measuring similarity with existing virus disease information, and dynamic analysis is used to detect new types of new virus disease information. Figure 9 shows the AI analysis module.

The AI analysis module static analysis analyzes the similarity between the collected virus information and the virus elements defined in the existing virus infectious disease classification system. Analysis is performed based on factors defining the infectious disease classification system, such as factors including infectious disease symptoms, infectious disease names, and epidemic periods. Dynamic analysis monitors and analyzes virus disease factors such as virus type, location of occurrence, transmission power, transmission power of infection, and existing virus factors based on matchmaker's mismatching information. The AI module analysis results are applied to the disease classification service matcher and disease control center by using the infectious disease classification system criteria. Disease classification service matcher applies matching information and analysis information to standard elements of infectious disease classification system in matchmaker and AI analysis module to support services by classification. The infectious disease classification system element uses the legal infectious disease classification system. Table 1 shows the legal infectious disease classification system.

3.5 Disease Control Center Service Support

The Center for Disease Control provides disease services based on the disease classification service matcher and AI analysis module information. It provides extended disease services including surveillance and containment applied in the existing disease classification system. The disease control center provides early response to virus disease by supporting services and prevention for each situation based on matching information and analysis information. The disease control center provides disease prediction and route information, induction of early examination in case of disease occurrence, diagnosis of virus infection, self-isolation monitoring, prevention and warning of infection proliferation, and post-management of infected patients. The disease control center can establish a unified support system with the service provider, enabling early response to disease. In addition, it provides various support services to virus disease service requesters to help prevent virus spread and effectively deal with infections in the infected environment. Figure 10 shows the services supported by the disease control center.

4 Comparison analysis

Virus-infected diseases are spreading rapidly around the world, and the frequency of outbreaks is rapidly decreasing. In order to solve these problems, research on various technological approaches that converge IT is underway. The IT/AI convergence virus disease control system model proposed in this paper extends the IoT environment and AI analysis to the existing single virus protection system and proposes an alternative that can actively respond, overcoming passive

Fig. 8 AI broker
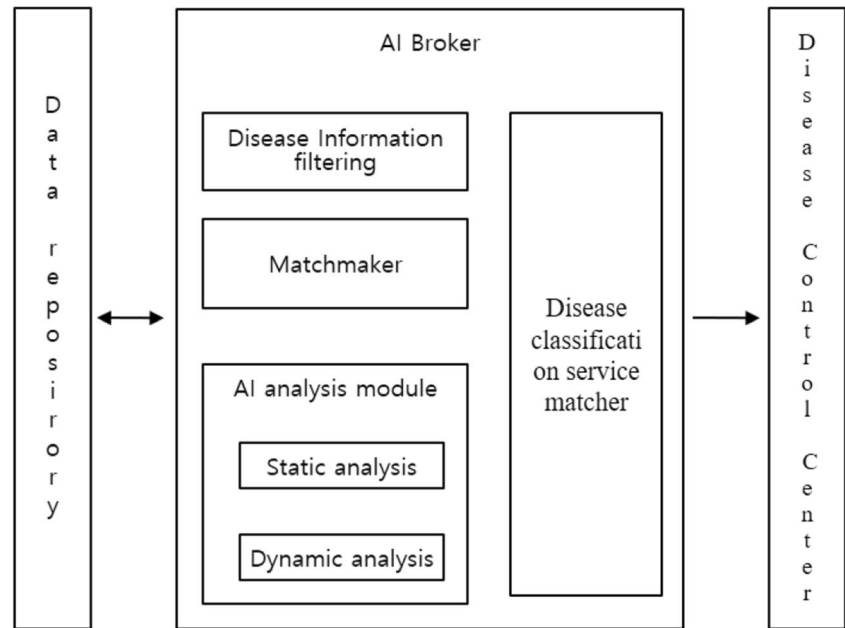
responses. Through the establishment of the IoT environment, it is possible to apply early prevention systems between countries or regions by collecting information generated in the region through early blocking of infected people and disease agent monitoring from the immigration stage. Information through monitoring can be actively dealt with through analysis of the similarity of existing virus disease through AI analysis module and registration of information on new viruses. The proposed system model can establish an integrated virus infection control model by implementing a unified system for analyzing virus infection information, responding to virus diseases, and providing service to infected people. Table 2 shows the comparative evaluation of the existing research and the proposed system model.

For virus disease analysis, smart thermometer and medical diagnosis and screening only determine presence of infection through information gathering. Disease surveillance supports the analysis of virus disease based on collected information. The proposed system performs disease analysis based on mismatching information and existing virus disease information through the AI module. Information collection method smart thermometer and medical diagnosis and screening are based on IoT devices, and disease surveillance is based on monitoring information. The proposed system collects disease information based on IoT device and agent monitoring information. For monitoring of virus disease, smart thermometer collects information based on user behavior. Medical diagnosis and screening, disease surveillance, and the proposed method perform monitoring using IoT devices and agents.
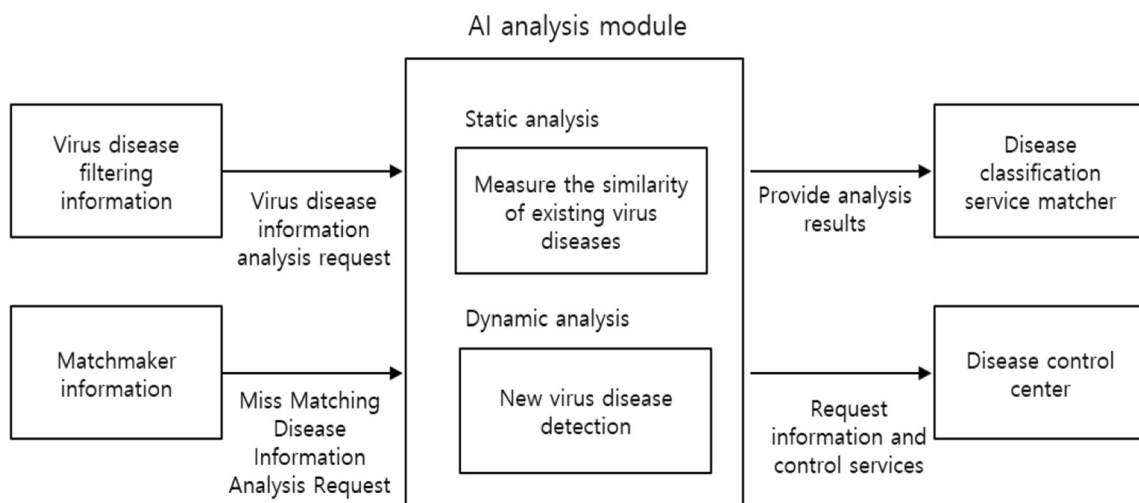

Fig. 9 AI analysis module

Table 1 Classification of infectious diseases

Division	Type	Control
Level 1 infectious disease	Bioterrorism infectious disease or high mortality rate, large outbreak concern, or infectious disease requiring negative pressure separation	Negative pressure isolation
Level 2 infectious disease	An infectious disease that needs to be separated and declared within 24 h of occurrence or outbreak in consideration of the possibility of illness diffusion	Isolation
Level 3 infectious disease	Infectious diseases that need to be declared within 24 h of an outbreak or epidemic to continue and monitor the outbreak	Surveillance
Level 4 infectious disease	In addition to Level 1 to Level 3 infectious diseases, infectious diseases that require specimen monitoring activities to investigate whether they become epidemic	Specimen monitoring

The response time, smart thermometer, and medical diagnosis and screening can respond after infection, and disease surveillance and the proposed method can respond early through information analysis before spreading. For post-management, smart thermometer and medical diagnosis and screening can be partially supported after symptoms of infection. Disease surveillance performs virus disease analysis, but not post-management. The proposed method supports post-management through the disease service provider in the Center for Disease Control.

5 Conclusions

Virus disease is spreading rapidly from regional epidemics to regional and international spreads. The spread of virus disease among countries goes beyond the problems of one country and causes social and economic problems worldwide. Various studies have been conducted to solve these problems. In this paper, a virus disease control system using an IoT/AI convergence model that can actively respond to infectious virus diseases is proposed. With the 4th industrial revolution,

research on smart disease prevention and containment systems is actively conducted using convergence technologies such as IT, AI, IoT, and big data on diseases. Although these studies can be applied to disease prevention and containment environments for a single region and country, they have limitations for preventing systems between regions or countries. The IoT/AI convergence disease control system model proposed in this paper aims to proactively respond early to disease spread and containment. The disease control system collects data from the early stages of virus diseases that have occurred from the outside through the IoT environment establishment, and it is possible to deal with the infection early. In addition, it analyzes the possibility of transmission and spread by measuring the similarity to existing diseases by collecting disease information through monitoring of virus disease information that is prevalent in a specific region. When mismatching data with existing virus disease information is generated, information on virus disease data is generated and a new virus disease prevention control service is supported. The disease prevention control service can support the systematic disease control service by unifying the disease control service from the initial stage to the infected person's post-management.
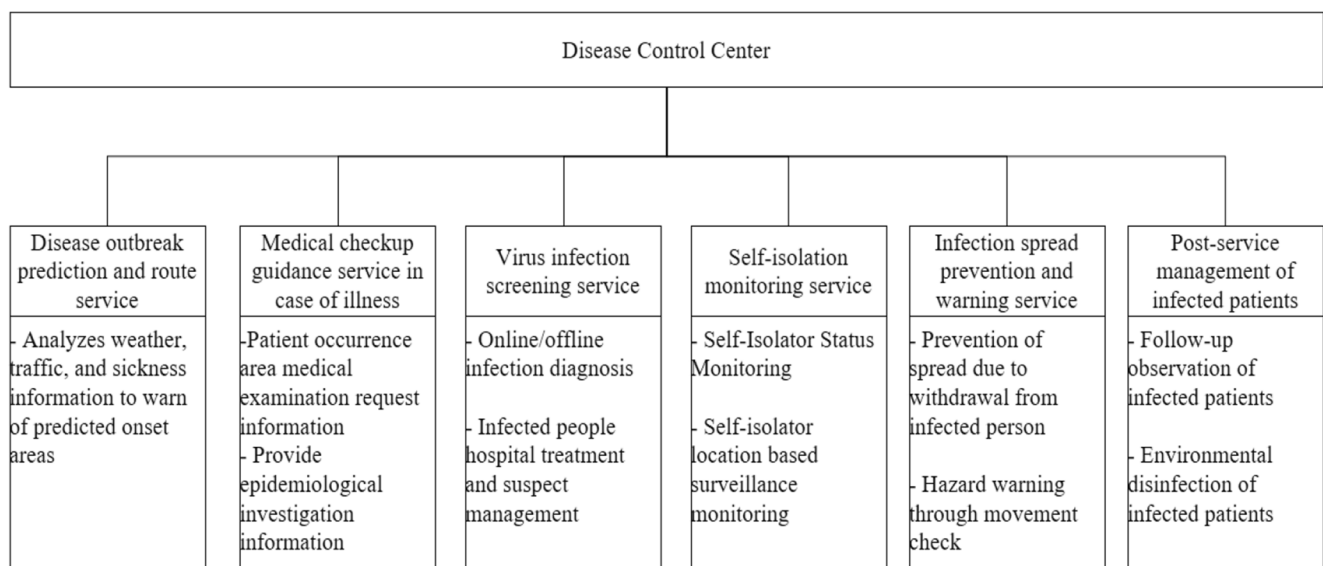

Fig. 10 Diseases control center service

Table 2 Existing research and proposed system model comparison evaluation

Method Item	Smart thermometer	Smart watch	Medical diagnosis and screening	Disease surveillance	Propose method
Virus disease analysis	No support	No support	No support	Support	Support
Information collection method	IoT device	IoT device	IoT device	Monitoring	Monitoring, IoT device
Monitoring	No support	Support	Support	Support	Support
Response point	After spreading	Afterspreading	After spreading	Before spreading	Before spreading
Post-management	Partial support	Partial support	Partial support	No support	Support

With the IoT/AI convergence virus disease control system proposed in this study, an integrated virus infection control model can be established. And we can achieve the proposed model through both the early detection and monitoring of infected patients before the spread of virus disease and the analysis of virus diseases in regions and specific countries, and through the early containment system according to the outbreak of new viruses. In the future, it is aimed to expand the analysis based on collected information to conduct research on an international integrated virus protection system model using big data. Another aim is to expand the system to predictable prevention systems for virus disease transmission and spread and early warning systems for virus diseases, with comprehensive information on the emergence of viruses reflecting regional and international characteristics.

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