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Using Internet of Things to Deal with Pandemic: A Use Case Based Framework

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Original Research

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Abstract

Objective: The objective of this study is to develop a conceptual framework for use cases applicable to the development of an Internet of Things (IoT) system, designed for intelligent environments capable of managing the pandemic.

Methods: To achieve this objective, a comprehensive content analysis of scholarly articles from MDPI, PubMed, and Google Scholar was conducted. Best practices were identified, and various application examples were synthesized to establish an IoT-based framework.

Results: The study proposes measures for the implementation of technologically advanced environments and services while ensuring public compliance with these developments. Based on the identified use cases and enabled applications, a conceptual framework was formulated. The key use cases for IoT applications include traffic management, patient health monitoring, early virus detection, remote work facilitation, smart hygiene solutions, tracking infected individuals, monitoring social distancing, enhancing health care facilities, and ensuring quarantine compliance. To ensure rapid and effective implementation of policies, regulations, and government orders, robust architecture, applications, and technological infrastructures must be developed.

Conclusions: This study explores new architectural frameworks, potential use cases, and avenues for future advancements in IoT-based applications. The use cases are categorized as near-field measures, hybrid measures, centralized control mechanisms, and their integration in the defense against COVID-19.

The World Health Organization (WHO) initially declared a global public health emergency on January 30, 2020. Subsequently, on March 11, 2020, the WHO officially classified the Coronavirus (COVID-19) outbreak as a pandemic.[1] While the world had previously encountered similar coronaviruses, their spread was limited to specific regions.[2] In contrast, the rate of transmission and global dissemination of COVID-19 was unprecedented. In response, nations worldwide have adopted innovative technological solutions to combat the pandemic.[3]

The spread of the infection has been progressively mitigated through social containment measures, including nationwide lockdowns, travel restrictions, quarantine protocols in high-risk areas, and limitations on customer capacity in essential businesses.[4] Researchers suggest that the integration of Internet of Things (IoT) technologies could have significantly reduced the transmission of the virus.[5]

It is anticipated that smart environments and technology will provide data-driven services with sensors installed to implement community-wide social distance measurement as well as to assist in the early detection of cases to effectively plan for future epidemics and enforce protocols. The management of quarantines, the control of COVID-19, and disease surveillance can all be aided in this situation by the IoT. This study's primary objective is to create a conceptual framework and many use cases for a data-driven system that is motivated by a smart environment and may support the activation and execution of community anti-contamination activities during high-impact, uncommon occurrences. It also emphasizes challenges and upcoming trends to enable future intelligent environments and get ready for pandemic crises.

Internet of Things and Coronavirus

The idea behind the IoT is to use an on/off switch to connect any device to the Internet and/or to one another. Data collection, transfer, analysis, and storage are some of the functional components that make up this notion, which is founded on the broad principle that "anything may be connected." As a result, the IoT is a paradigm that links intelligent things together through the Internet so that data may be managed and used to achieve the desired.[6] IoT enables a virtually limitless number of connections and opportunities and offers countless prospects for both business and society.[7] IoT applications are being used by more and more businesses and consumers to cut costs and improve operational efficiency. A "perfect storm" for IoT is created by all these applications.[8]

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Internet of Things Architecture

The use of mobile applications, smart devices, biosensors, wearable technology, home virtual assistants, predictive analytics, and health portals by health care organizations today is based on IoT technologies. The diversification of current Internet services is the context, and the architecture contains the following 4 layers:[9]

Sensor and Link Layer: The bottom layer of the IoT architecture is called the Sensor, Link, and Network layer, and it contains the sensors, RFID tags, and the network that gathers data.

Gateway and Network Layer: The embedded operating system, signal processors, microcontrollers, and gateway networks such as local area networks and wide area networks are all included in the layer known as the "gateway and network."

Management Service Layer: Data mining, text mining, IoT device service analysis, information analysis flow analysis, data analysis, and device management are all responsibilities of the management service layer.

Application Layer: This layer is in charge of making the most use of the data that labels and sensors gather.

In the period of the pandemic, it is critical to strengthen digital infrastructures to reduce the effects of current and possible future crises and to effectively analyze citizens' mobility, disease propagation trends, and health status monitoring.[10] With smart technology infrastructure, necessary precautions should be taken concerning social inclusion in cities/countries, and it should be ensured that disadvantaged groups without Internet access, et cetera. are not left out of the process.[11] Another issue is that public and private sector organizations should take care to manage privacy concerns while determining measures to be taken and paying attention to data usage.[12] IoT is a cutting-edge technology in this regard to lessen viral infection. The following are important benefits of IoT for the COVID-19 pandemic:[13]

- Reduces chances of mistakes
- Lesser expenses
- Enhanced diagnosis
- Effective control
- Superior treatment

IoT Devices Used in the Pandemic

IoT applications are used to make sensors accessible and combine many sensor data to produce information. They provide the transmission of a high amount of sensor data from physical environments to operators or related people after the evaluations are made and processing of the data is done with the help of IoT systems. The devices in the IoT realm can be mentioned as follows.[14]

Drones

In the COVID-19 pandemic, the use of unmanned aerial vehicles and other air surveillance technology can make it easier to put containment and social removal measures in place, reducing the number of face-to-face encounters and exposure to the virus.[15] The primary benefit of deploying drones is their ability to reduce direct virus exposure by requiring fewer operations while carrying out technical duties. While reducing unwanted human contact dramatically, drone deliveries of consumer goods and medical samples can help people in isolated or quarantined places get necessities. Drones, such as 5G Patrol Robots, advise people to cover their faces. Thermal imagers are used to measure human body temperature, and drones are utilized to sterilize large areas.[16]

Robots

Health workers' robots began to take part in the treatment process to minimize contact with the patient. It has been revealed that using robots during pandemics such as COVID-19 can reduce virus transition from person to person, support patients/health care professionals, and clean medical equipment, food, and logistics.[17] The robots can monitor parameters via medical equipment in the room and pass the necessary details to hospital staff. The obligatory "social distance" restriction due to the very rapid transmission of the virus from person to person during the coronavirus epidemic causes people to distance themselves from each other, while shortening the distance between robots and people. While the use of robots is not limited to the health sector, service robots are also used for those who have to stay alone at home, and they are being used more frequently in the service industry, such as hotels.[18]

Connected Thermometers

Hospitals scan staff and patients using connected thermometers. It continuously monitors COVID-19 patients using temperature sensors to reduce the risks to hospital staff. Body temperature sensors provide continuous, real-time monitoring of temperature changes. An IoT access controller is needed to wirelessly communicate real-time patient data to a nurse's station for continued monitoring. This permits the pairing and connection of up to 40 Bluetooth low-energy devices simultaneously while providing the long-range connectivity necessary to cover many rooms.[19]

Smart Wearables

Researchers have created sensor-equipped clothes that can track bodily functions. Users receive warnings from the smart band when their body temperature rises above 37.5°C. When a smart band detects movement in the human body, it emits radio signals that allow it to determine how far away another bracelet is. The 2 smart bands vibrate when they are close together, sending a signal that encourages people to respect social distances. The app works with smartwatches and sports wristbands and recognizes various symptoms related to coronavirus infection in the user data through an algorithm by collecting its data, including heart rate, temperature, and sleep, to analyze whether users have signs of disease. Results are displayed on an interactive online map.[20] T1 Thermal Goggles instantly measure the temperature of other people. Governments, businesses, and schools are equipped with an infrared sensor and a 12MP camera that allows people to read temperature with glasses. Besides constant temperature measurement, T1 can provide portable, remote, and fast temperature control, which will be very helpful.[21]

Thermal Cameras

In areas where there is human activity, thermal camera system uses automated systems that include infrared thermal cameras to scan for fever from face temperature measurements. Measurements take place almost instantly; there is no contact, and since data can be viewed remotely, there is minimal risk of distortion and cross-contamination or damage to the operator in public places. By simply attaching a thermal imaging lens to the CCTV camera, the face recognition system can detect the body temperatures of mass groups. If a subject with abnormal body temperature is detected, a warning appears on the screen and can be sent to the relevant personnel if necessary. This alert can be instantly done with an alarm or a mobile

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message. With the identified and recognized person, the system can also monitor the received body temperature.[22]

IoT Buttons

IoT buttons can be used to quickly raise an alarm for vulnerable individuals or to alert other staff members. IoT buttons immediately inform management of cleaning or maintenance problems that can endanger public safety. The button monitor can cling to any surface, is distributed by employees or the general public, and doesn't operate on infrastructure. IoT buttons can be utilized in patient rooms, care stations, and public spaces. The portable LoRaWAN emergency push button features a simple switch button that is activated when pressed. This device uses a tact switch that is easy to operate and easy to carry. When the emergency button switch is pressed, the alert signal is sent to a centralized monitoring system via the LoRaWAN protocol. "Safe" signals are also sent periodically to report range and battery status.[23]

Biosensors

The sensor is not yet ready to gauge the airborne coronavirus density. However, once the sensor is complete, this idea can be used to other viruses, aiding in the early detection and halting of an outbreak. In the future, this biosensor can be used to gauge the viral density in hospitals or tight spaces.[24] Researchers are working to measure, analyze, and reduce air-polluting elements such as aerosols and synthetic nanoparticles. The COVID-19 pandemic, however, also modifies the objectives and plans of laboratories engaged in several disciplines. The rapid and accurate detection of coronavirus is the new focus.[25]

Internet of Things Use Cases in the Pandemic

The COVID-19 outbreak demonstrated the benefits of intelligent applications, remote management of operations and production lines, and monitoring and maintenance of facilities. In the COVID-19 crisis, IoT has been shown to play important roles in modernizing health systems, crisis management, public health and safety, supply chain, and production. It should not be overlooked that smart applications will have superior benefits not only in times of crisis but also after this period.[26] Important use cases are as follows:

Compliance With Quarantine

IoT can be used to find an outbreak's starting point. IoT devices can be used by regulatory agencies to monitor symptomatic assets for illness symptoms when the degree of spread is lower. Using IoT-based mobile application development, it is possible to improve suspects' monitoring operations and stop widespread outbreaks.[27] IoT can be used to monitor compliance once it has identified possibly infected individuals for quarantine. When patients are isolated, public health personnel screen them and may keep track of who broke the quarantine. They will be able to hunt down anyone who is exposed to the infraction with the aid of IoT data. Remote cameras, drones, and other IoT-based monitoring tools can efficiently check if people are adhering to quarantine protocols.[28]

Managing Patient Care

The IoT's scalability is also helpful for keeping track of all patients who are at high risk of quarantine but who don't need hospital care. With the help of IoT and cloud data, patients can take their temperature and send it to their mobile devices for analysis. IoT has previously been used to remotely monitor patients with chronic diseases like diabetes or hypertension who are receiving care at home. To monitor a large number of patients with a few staff, wearable devices and wireless devices for patients have been utilized to communicate biometric parameters like telemetry, heartbeat, and blood pressure to central monitoring. Here, IoT can be utilized to lessen the risk of infection for health care personnel, collecting more data in less time to lighten the strain and boost productivity.[29]

Early Detection

It is possible to prevent disaster when data scientists can monitor the origin of a virus outbreak in time. In this context, IoT seems to be a suitable solution as it can accurately detect the contamination site by analyzing the mobile phone data of millions of users. Most users of smartphones are connected to the Internet, a geographical information system to track the location history. If the majority of infected patients have previously been in the same geographic area, it is likely to be the point of transmission. After determining the origin, the authorities can take strict measures to lock the entire area. They can also easily monitor any person who comes in contact with infected patients and keep them alone.[30]

Development of Medical Facilities

The biggest challenge for any country during an epidemic is to provide adequate medical facilities to infected patients. If the contamination rate is fast, enough material is needed for new patients as others heal. Another major challenge that can arise is the scarcity of test kits and the slower detection of the virus. The use of IoT-based equipment ensures the prudent use of existing test kits and helps medical facilities. IoT-based mobile and wearable applications make it easier to identify people at high risk of infection. Health authorities can make the most of existing test kits by prioritizing the tests of high-risk people. Doctors can use IoT equipment to remotely monitor health conditions, rather than performing daily checks on healing patients. IoT-based mobile application development services proactively provide monitoring and comparison of patients' health data.[31]

Work From Home

COVID-19 required millions of workers to work remotely. Technicians may monitor and maintain performance with remote IoT applications without needing to be on the job. IoT sensors that are linked to cloud software platforms send real-time data on machine status, usage, and even temperature to the person in charge. IoT devices warn technicians to take action if specific thresholds are crossed.[32] IoT devices in the health care industry enable staff to remotely monitor patients' vital signs while they are in the hospital or at home, enabling them to take on the role of virtual caregivers and provide recommendations and diagnoses depending on the data they receive. To create real-time monitoring solutions for health care, many health care experts predict the growth of IoT applications for telehealth.[33]

Hygiene With Smart Sinks

Soapy Care has developed what they call "Smart Sinks" with the tagline "Your Hygiene at Your Fingertips." These standalone stations

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use IoT sensors to dispense the exact amount of soap or sanitizer to use. The water temperature needed to properly wash your hands is controlled by the IoT. With different settings recommended for homes, restaurants, daycares, or senior centers, these handwashing stations ensure hygiene for everyone and ultimately, no shortcuts. Soapy Care systems are already available in the US, Africa, and Asia, and washing hands with soap under running water is an important intervention to prevent the spread of COVID-19.[34]

Tracing Infected People

Thermal cameras were used to diagnose infected people, but the main disadvantage of this method was the use of people. Now, multi-sensor cameras supported with artificial intelligence (AI) are being used in public places such as airports, hospitals, and kindergartens.[35] Along with these developments, Google and Apple recently announced that they are cooperating to follow COVID-19. The project they are developing aims to examine who has been in contact with smartphone users individuals for a long time to catch coronavirus with Bluetooth Low Energy (BLE) technology and who is approaching. One of the advantages of this project is that users don't need to download any apps from virtual app stores. Devices and existing sensors are considered to be used for the implementation of this method. While doing this, it is aimed to highlight privacy by not using any location or personal data.[36] With the platform developed by Apple and Google, all of these third-party applications are aimed to achieve integrity among themselves by gathering them under 1 structure; applications can work in harmony with each other and coronavirus is detected even during international travels.[37]

Proximity Trace

Employees are alerted when they are very close to one another by the IoT system's proximity removal warnings and contact tracking, which are worn via wearable devices and emit progressively louder alarms. The technology can be used to make contact tracking utilizing passively acquired historical data to identify other exposed persons if an employee tests positively.[38] It was created to prevent employees from being exposed to COVID-19 at work. The use of wearable technology, a crucial aid in flattening the COVID-19 curve, and in-the-moment social distancing is the solution for anonymous contact tracing. Employers receive alerts, and monitor and evaluate information on social interaction and distancing in their workplace because employees receive automated proximity warnings in close to real-time on their devices while at work. The information can be utilized to generate feedback to enhance processes and training.[39]

Big Data and Artificial Intelligence

The data source can act as a tool to create multiple large data and AI systems that can provide value by enabling and implementing measures. The big data systems can inform the graphic hot spots and the local government about the areas that the population frequently visits and which should be monitored regularly. Finding these traffic hot spots is also necessary at the disinfection stage.[40] The IoT can also be used to track vehicles on a certain road. This specific information can be used by local law enforcement to create policies that enable the implementation of social distance measures. An exemplary case of such a situation is tracking vehicles from regions with multiple COVID-19 cases. AI-based registration plate readers can be used to read status registration plates that can inform local authorities about the origins of a vehicle. Utilizing big data and AI applications will help to prioritize specific locations with proven traffic points.[41]

Distant Face-to-Face Teaching

It is seen that the continuing restrictions due to the pandemic will change the way of teaching and learning. The common point of all stakeholders is that the use of digital channels will gradually increase and develop in the future. By using distant face-to-face management, it will be possible to transition to a disciplined working method, and it will also contribute to the harmony of digital change in the new world order. With the distant face-to-face method, the teachers and students can transfer the messages that the teaching needs to transmit digitally. The importance of this will both protect the health of the teachers and students who want to meet face-to-face and teach and learn with a safe method and will accelerate their transition to digital platforms. It is required to install the necessary programs on the phone, tablet, and computer to be contacted for technical support. It is stated that digital methods should be developed to make this method faster. Disconnections and slowdowns in Internet connections will negatively affect the work, and the use of digital channels in data transfer will make teaching more effective on both sides. As a solution, a fast and easy working model can be developed without the need for an Internet connection by using Bluetooth technology in distant face-to-face eaching.[42]

Methods

In this study, content analysis of academic articles was conducted, good practices were examined, and various application projects were combined to obtain IoT applications to cope with COVID-19. The mentioned use cases were grouped into 3 categories: near-field measures, hybrid measures, and central measures, which ensures no gaps between them. The proposed conceptual framework includes the requirements and supporting procedures to be used to implement social measures for social distancing and personal safety. This framework provides a standard starting point for developing and executing the system to provide alerts and data-driven applications while minimizing the negative consequences of potential concerns about multiple stakeholders.

The practices of countries against the pandemic were expressed in various international organizations. In this context, United Nations programs were examined. The United Nations Development Program report "The Impact of the Pandemic on Peace, Justice, and Inclusion (SDG 16)" was examined and the good works of the countries were determined.[43] In Europe, Eurostat data on 29 European countries were investigated to get information about practices.[44]

The framework includes 3 main components. These components are grouped according to the functional services and controls controlled by a cloud-based network. There may be occasional overlap in measurements. However, this is not a major issue. These components are:

Near-Field Measures: Concerns sensors, networks, and devices in the immediate and personal space.

Hybrid Measures: Measures that are hybrid in nature deal with both services and social distance. Locations are in hospitals and public spaces.

Central Measures: Covers services and actions provided by businesses and the government in numerous locations.

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The framework can, in general, record real-time data from surrounding personal area sensors, smart linked devices, and central cloud management systems, as well as communicate with nearby businesses and analyze associated data. The real-time low-latency connectivity offered by such intelligent physical devices is enabled by mobile systems. The framework's adaptability to different usage scenario requirements and its support for hybrid usage and the cloud enables the processing of dynamic real-time needs using centralized cloud infrastructures.

To get certificates and guarantee the validity of communications sent between institutions, participating systems—including automobiles, surveillance systems, drones, and various sensors and devices—must be registered with a central authority. Messages can be sent through cellular LTE, WiFi, 5G, or special short-range communication technologies. Additionally, the Message Queuing Telemetry Transport (MQTT, data exchange protocol) communication protocol is frequently used to support the physical presence of cloud service providers. To accommodate various usage scenarios, this framework will require more than 1 technology and communication protocol. Communication is possible between various physical items, cloud-supported services, and peer-to-peer models, as depicted in Figure 1. To make it possible for hundreds of smart devices to communicate with one another, such infrastructures and supporting technologies will require long-term investment and collaboration between public and commercial organizations.

The IoT conceptual framework focuses on the platform for data sharing between interested parties that can aid in accelerating building reaction times and putting emergency measures into place. Real-time data sharing across environmental stakeholders can help to facilitate the adoption of more effective and automated response methods. For instance, drones can convey messages with traffic lights to collect social distance limits, gather data on the population, and reroute traffic. Based on the number of infected individuals, the sensitivity of the infection, or the suspected infected communities, automatic disinfectants and fogging can be applied to certain regions at the same time. Cloud services allow for the real-time sharing of parking space availability, and participants can complete tasks with little assistance from other people. Low response times in intelligent environments and more effective resource management in the impacted areas are made possible by these applications. Continuous observation, data gathering, and real-time communication can be used to create a safer atmosphere that is more effective and productive.

Challenges and Opportunities

IoT systems and use cases provide a conceptual overview of current use case studies in the world, providing a basis for comprehensive research and deployment of automated data-driven technologies from smart environments and intelligent systems. The proposed framework and AI-enabled smart applications discussed in the paper

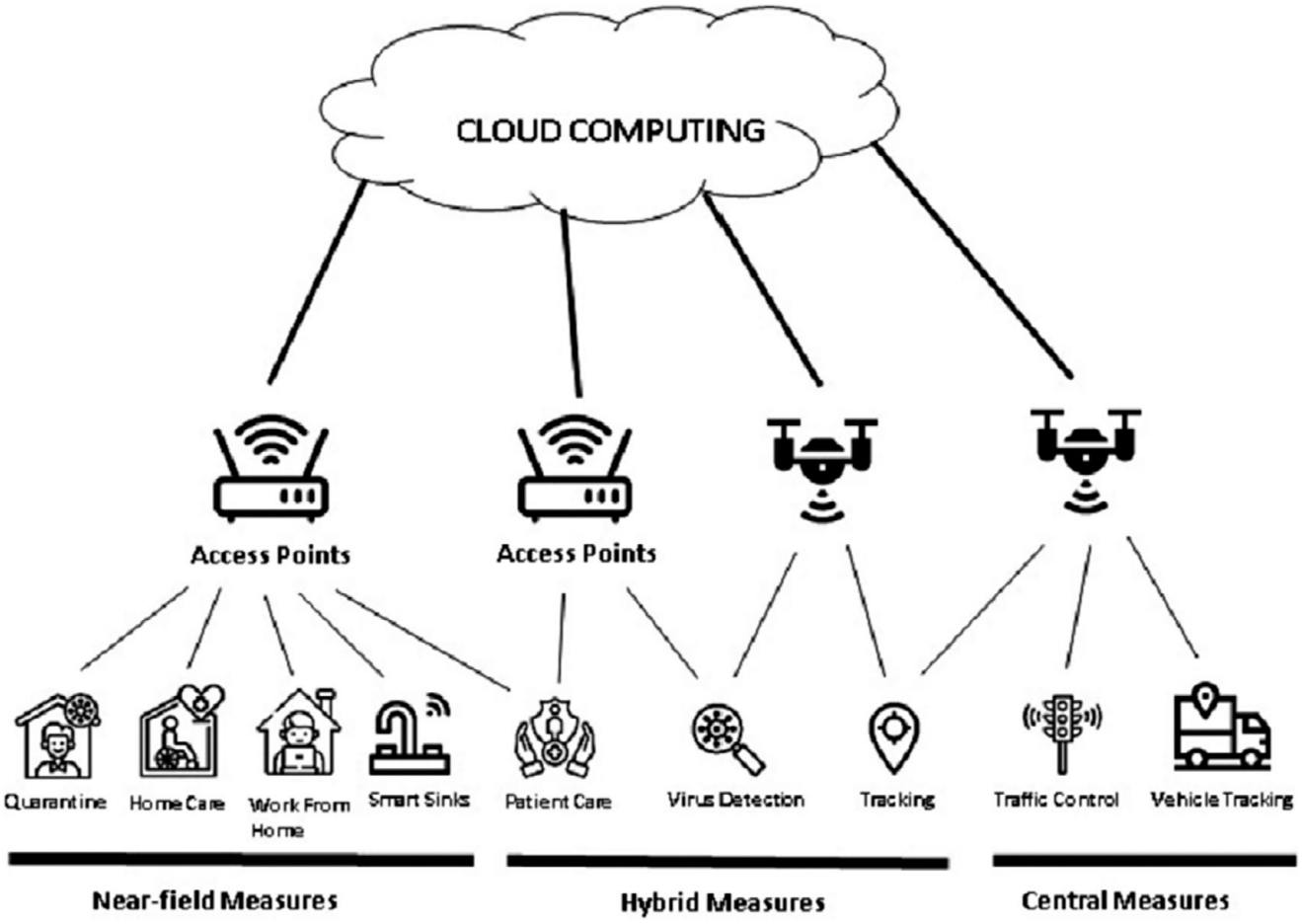


Figure 1. A holistic view of the IoT conceptual framework.

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can be used to implement effective and timely social distancing community measures and optimize the use of resources in critical situations. In addition, a conceptual set of recommendations and future directions for the effective use of digital technologies are outlined. The use cases outlined are anticipated to be developed based on the AI-driven IoT to ensure that these applications are more widely adopted in society in the future, and to ensure that there are no gaps between them. The integration and response of digital technology into pandemic policy may be one of the few characteristics of countries that have flattened COVID-19 incidence curves and maintained low mortality rates. In the race to control the spread of a highly contagious virus, countries that rapidly use digital technologies to facilitate planning, surveillance, testing, contact tracing, quarantine, and clinical management are at the forefront of managing the burden of disease.

In this unique era, one of the biggest issues facing many nations is the availability and accessibility of digital technology. The relationship between technology and society will undergo structural changes as a result of the COVID-19 epidemic, with obvious repercussions in numerous domains. Depending on their communication infrastructures, many countries have made remote working, a partial working method, depending on their communication infrastructure, a standard in the commercial world. Since the COVID-19 pandemic has caused hundreds of millions of pupils to miss school, some countries have implemented online distance learning and virtual learning programs. The majority of meetings and events, ranging from small business gatherings to medium-sized and huge conferences, and the highest-level political gatherings of leaders of state have taken place online and through video conferencing. Various colleges and research institutions across the world have hosted hundreds of thousands or millions of webinars and virtual meetings on the diverse aspects of this epidemic. In order to avoid or reduce risks for both patients and providers, virtual medical consultation is quickly becoming the new standard.

Despite the numerous advantages, the necessity of using digital platforms has presented several governments in low- and middle-income countries with some fundamental challenges. These challenges include the possibility that inadequate information and communications technology (ICT) infrastructure, especially in many rural and slum areas, can impede the use of cyberspace capacity and worsen already existing disparities in communities' access to services. Furthermore, even in more developed nations with robust digital infrastructures, a prolonged COVID-19 pandemic may result in a reduction in Internet capacity. The pandemic and the lessons acquired could give many nations the chance to rebuild their health systems toward increased surveillance and readiness, as well as to plan and execute the required actions to reach out and restore international confidence, despite its catastrophic hurdles. All nations and their governments are reminded by the epidemic of the value of multi-sectoral and cross-sectoral cooperation both inside and between their borders. Authorities worldwide are reminded by COVID-19 that outreach is more important than ever.

Conclusion

The COVID-19 epidemic has had an unimaginably devastating influence on everyone's lives globally. People worldwide now have access to various research opportunities and challenges that can help them reduce their risks and prepare for the future. The suggested architecture and the smart apps powered by AI presented in the article can be utilized to implement social distancing community measures successfully and on time as well as to maximize the utilization of resources in urgent circumstances. This article offers a conceptual overview and evaluations of current use cases, and lays the groundwork for in-depth investigation and use of automated data-driven technologies derived from intelligent media and intelligent systems. Additionally, it is suggested that the identified use cases be organized as near-field measures, hybrid measures, and central control measures to ensure that there is no gap between them and that IoT may be used effectively against COVID-19. For these applications to be more extensively adopted in society, it is projected that future development will be built on the IoT and AI.

Author contribution. Alaattin Parlakkılıç: Design, methodology, data acquisition, analysis, interpretation of data, drafting the work and revising it critically, and final approval of the version to be published.

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