Chapter 3
COVID-19, Sensors, and Internet of Medical Things (IoMT)

Introduction

The IoT empowered automatons are being used for observation to guarantee user isolation and face mask usage to cover the face adequately. These innovations can be utilized for following and identifying the source of an outbreak. It can be useful to the disease transmission specialists to identify persistent zeroeth patients and to recognize the people interacting with these patients. The patients who break the isolation can likewise be found. Additionally, this innovation can be a potential candidate for giving help to the clinical staff by remote monitoring and observing in-home patients and staying away from physical contact.

The IoT is utilized for different applications to satisfy the significant necessity of countering the COVID-19 pandemic impacts. It can evaluate the upcoming circumstance with the assistance of acquired information. Its uses are applied for legitimate administration of this pandemic. The patients can utilize the IoT framework for reliably observing the pulse rate, circulatory strain, glucose level, and different exercises for customized consideration. It serves the purpose of the ceaseless screening of the wellbeing states of more individuals. One of the critical uses of this innovation is to follow the constant area of clinical gear and devices for a smooth and effective treatment process. This makes the treatment work process of the patient effective and supports dynamic procedures for complex cases. The IoT paired with artificial intelligence (AI) technology can be deployed to automate or scale tasks, including patient tracking, quarantining, monitoring, and in-hospital care, as shown in Fig. 3.1.

A self-governing IoT empowered police robot can be used for watching the regions to affirm that the individuals are following the lockdown conventions appropriately. The self-governing police robots can be sent to the medical clinics to help the well-being laborers play out their obligations with no interruption—this aide in improving the presentation of the clinical staff and containing the spread of the COVID-19.
Sensor Systems for COVID-19

Regarding COVID-19, relevant information about patient healthcare includes information on doctor–patient arrangements, clinical pictures, doctor notes, case history, chest X-ray reports, and data about episode zones, among few others. This information is produced from various sources, starting from the Internet of things (IoT) sensors (e.g., smartphone information) to online social stages (e.g., open responses). The conventional information systematic apparatuses and components are not satisfactory for meeting the prerequisites during the COVID-19 pandemic. The sensor system for medical services/applications can have the following generic stages, as shown in Fig. 3.2.
### Multi-level process of IoT sensor data processing

| Level 1 | The formation of integrated channel of devices, sensors, monitors  
The data collection and analysis |
| Level 2 | The data conversion process for uniform format and meaning  
Data processing after completion of data transformation |
| Level 3 | The concept of cloud based computation is incorporate at this stage,  
The data aggregation and standardization |
| Level 4 | Advanced data analysis and data management  
Report generation, patient database creation, and decision making  
Prognosis and advisory based on learning models and feedback. |

Modern smartphones are embedded with a large number of sensors and possess powerful computing facilities. It is possible to sense information about daily activities and also to capture visual data using smartphones. Smartphones are capable of capturing, collecting, communicating, and storing large volume data from either suspected and confirmed COVID-19 patients. A smartphone can scan CT images of a COVID-19 patient and upload them to the cloud for analysis purposes. Even multiple CT images of the same COVID-19 patient can be examined by the smartphone for comparative analysis to determine how lesions have developed over a period of time. The investigation is beneficial to the suspected COVID-19 cases to diagnose and monitor the grade of lung inflammation. A multi-level sensor data processing model is presented in Fig. 3.3.

Specialists at the Swiss Federal Laboratory have built up a sensor that might rapidly and dependably distinguish SARS-CoV-2, i.e., the COVID-19 infection. Preceding the coronavirus spreading far and wide, Jing Wang and his group investigated sensors that could detect microscopic organisms and infections that were noticeable. The idea of the sensor technology would not supplement the setup research facility tests, yet could be utilized as an alternate strategy for a clinical analysis to quantify infection in the air in a continuous manner. The sensor could be used in crowded and sensitive places like train stations and emergency clinics.

The sensor highlights optical and thermal impacts to identify the infection reliably and securely. It depends on small structures of gold nanoparticles on a glass substrate and DNA receptors that coordinate explicit RNA groupings of SARS-CoV-2. The receptors on the sensor are similar arrangements to the coronavirus’ interesting RNA successions to help reliably distinguish the infection. Wang and the group of scientists
utilized restricted surface plasmon reverberation to detect the infection. The innovation uses an optical marvel that occurs in metallic nanostructures. They optimally balance the incident frequency that reaches to make a close plasmonic field around the nanostructure. When particles bind to the surface, the neighborhood refractive index changes in the close plasmonic field and indicates the infection [1].

Nations have demonstrated that it is possible to lessen the spreading of the SARS-CoV-2 or novel coronavirus infection by executing robust defensive measures while attempting to prop the economy up. In the USA, the Centers for Disease Control and Prevention (CDC) suggests the day-by-day wellbeing checks of employees before they enter the worksite. The World Health Organization (WHO) likewise recommends the temperature screening at the working environment. One of these measures is the utilization of non-contact infrared thermometry temperature estimation to screen for raised skin temperatures (EST) in the working environment. Employees and guests can have their temperature screened before they enter the workplace. This is one of the apparatuses to keep manufacturing plants, structures, building locales, organizations, or offices of any sort to open for regular business and ensure that everybody stays safe.

Infrared sensors and thermal cameras screen for elevated skin temperature. Skin temperature is not the same as the body temperature but can be accepted as the body temperature under normal environmental conditions [2].

**Disease Tracking Through Crowdsensing**

Crowdsensing-based disease tracking (CDT) requires sensor networks and groups of people or volunteers (crowd) with mobile/smartphone devices capable of sensing, collectively sharing disease-related information (e.g., early symptoms, nearby infected persons, deciding to self-quarantine). The success of CDT is mainly dependent on the observation that individuals tend to proactively volunteer in contributing data about the COVID-19 spread using their smartphones, wearables, or other devices with sensors and available communication connectivity. CDT is relatively less pervasive and requires the active participation of people and physical hardware sensors in contrast to the Social-media-driven Disease Spread Indicator (SDSI [3]) [4]. However, the data in the CDT framework is less noisy and hence more reliable. Figure 3.4 [5] shows an example of a representative CDT system. A CDT may typically incorporate three main components.

1. Data collection platform: Data collection framework is the first component which consists of a connected network of users with a customized smartphone application to log observed data, and a set of IoT devices (e.g., activity tracker, smart heart rate monitors, thermal scanners). The smartphone applications allow authorized users to contribute their reports about COVID-19 actively. If the users choose to input data, the mobile app lets them conjure at what granularity (e.g., state, county, street, house) they are comfortable sharing their location information.
2. Data analysis framework: The analytics framework applies relevant statistical analysis and artificial intelligence (AI) techniques together with machine learning (ML) on the collected data to infer probable regions of infection and relatively safe zones. To conserve bandwidth and faster expedite processing, the smartphones’ computational power can also be harnessed to execute the AI algorithms at the edge.

3. Smartphone application framework: The smartphone application framework on the end-users’ mobile phones visually represents the analyzed geospatial distribution of the inferred regions. The app can obtain the required information from the backend server depending on the user queries (e.g., checking the risk level of a particular area of interest). In most cases, the data collection, processing, and representation are carried out in the same smartphone application. The Singapore and South Korea governments have launched mobile apps that utilize crowdsourced data to trace community transmission of the COVID-19. The government of India also launched a similar application (although not precisely the same) named “Arohya Setu” for crowdsourced contact tracing.
UAV-Based Health Surveillance and Alerting

Unmanned ariel vehicle (UAV)-based health surveillance and alerting (UHSA) systems have emerged as a new dimension of solutions to mitigate the challenges that evolved due to the urgency of the COVID-19 outbreak. With the help of many onboard sensors (e.g., optical and thermal cameras, GPS, accelerometer, gyroscope, microphones), UAVs can gather information remotely during a disease pandemic scenario where the ground units and human patrol teams cannot operate due to risks of getting infected. For instance, UAVs can assist in detecting unwanted crowds of people in the locked-down areas of a city through the onboard camera images. Figure 3.5 demonstrates a representative UHSA model for deployment to mitigate the COVID-19 spread [4].

The UHSA system responds to individuals’ emergency requests through social media posts or user-operated dedicated IoT devices about unnecessary mass gatherings. The data obtained from the UAVs and users in a backend server is processed using social sensing approaches based on statistical analysis, deep learning, and machine learning for analyzing and ascertaining the truthfulness of the data. The information is then updated across nearby regions by sending messages, raising verbal alerts, or alarm sirens through speakers installed on the UAVs. UAVs are also dispatched to different areas of a city to scan and obtain situational information about the region proactively. Using the onboard sensors and image classification algorithms like convolutional neural networks (CNNs), UHSA detects whether people violate the rules during the lockdown situation (e.g., by roaming outside, gathering in crowds, not following prescribed social distancing). The framework may also locate

![Diagram of UAV-based health surveillance and alerting system](image)

**Fig. 3.5** UAV-based health surveillance and alerting system
and verify the availability of critical supplies using the UAVs (e.g., open pharmacy, grocery stores) based on social media posts. Using the onboard speakers of the UAVs, the people violating the rules are advised to return home.

A real-world example of UHSA during the COVID-19 ordeal is in California, USA, where the law enforcement officials have resorted to utilizing drones for patrolling the state of California during the ongoing lockdown situation. During the COVID-19 crisis in China, UAVs have served multiple roles, including post-epidemic aerial evaluation, alerting, and relief distribution to affected regions. The representative model of the UHSA system is shown in Fig. 3.5.

Ongoing IoT Research for Addressing COVID-19 Challenges

1. Empowering and enforcing social distancing measures utilizing smart city and the associated IT infrastructures:

A COVID-19 pandemic has uncovered and exposed the limitations of the current organizations. Accordingly, engineering, technology applications, and innovation frameworks should be leveraged for a quick and effective response to the COVID-19 and similar challenges. This section attempts to describe the novel engineering, potential use cases, and some possible future advances in developing such applications utilizing the smart city and its available infrastructure [3]. COVID-19 outbreak is unprecedented and has disrupted the lives of millions of people across the world and paralyzed the economy. This pandemic has opened several research challenges and opportunities that our community is capable of and must address to equip itself to mitigate the present crisis and the future [3]. The smart city IT infrastructure includes edge devices, a reliable communication module, storage and computation cloud services (both private and public), intelligent computing platform, informed and smart users. There are many devices like the CCTV network, widespread availability of smartphones, smartwatches, various type of GPS-enabled tracking devices, Bluetooth-enabled devices available in the smart city IT infrastructure. All these devices collect massive data that can be analyzed through video processing, proximity detection, people counting to find out whether social distancing, face cover is being strictly followed or not?

2. Internet of Medical Things (IoMT) for remote monitoring of patients

The IoMT is a special case of the Internet of things specially designed for medical applications and services to assist individuals and medical practitioners. IoMT can help in screening, detecting, informing and advising the patients, caregivers, health administrators, and doctors to provide proper healthcare and ensure timely and genuine information dissemination and contain the issues before they become serious. In this sense, the authors [5] proposed a model, namely Assisted Reproduction Treatment (ART), to decrease the number of medical clinic visits, diminish
medicinal services costs, improve patient care, and reduce the cost and inconvenience. Thus, an IoMT-based innovative proposition to oversee and control the solution of pharmacological medicines to patients who have completed and used ART formats [5].

One of the significant benefits of IoMT-based remote wellbeing monitoring is the possibility of providing remote assisted living and wellbeing monitoring of the patients under continuous observation in isolation, combined with the advantage of low medical clinic bills. The ordinary remote monitoring frameworks cause lots of inconvenience and discomfort to the patients because of the size and form factor of the modules to be wearable in the body and the frequent charging or replacement of batteries. The IoMT concept’s evolution addresses these issues by designing and developing compact, ultra-low power sensor modules, low power and small-sized controllers, and lightweight communication protocols.

The remote wellbeing checking system mainly consists of a dynamic and flexible patient observing unit (PPMU) at the patient’s home or emergency clinical assistance vehicles and ongoing checking with the support of available networks at the hospital. The PPMU mainly consists of sensors and electronic circuits which are good and suitable for acquiring vital parameters. The vital parameters are pulse rate, pulse changeability, breath rate, systolic circulatory strain, diastolic blood pressure, oxygen immersion, internal heat level, body mass index, total lung volume, blood glucose level, and a few other parameters. It also has a processing unit to process the received sensor outputs and a communication submodule to uploads to the server for additional investigation and analysis.

The schematic diagram of PPMU in the patient’s home or an emergency vehicle is shown in Fig. 3.6 [6]. Doctors can always use a good and useful user-friendly

![Fig. 3.6 Generic architecture of IoMT [6]](image)
graphical user interface (GUI) to monitor and check patients’ state. The general remote checking frameworks depend on the type of disease and associated infection pattern [6].

“When to eat, what to eat, how much to eat, and how often to eat” are the most important questions one ponders for ascertaining good health. Not able to decide on these in an optimum manner leads to several medical problems. In iLog [7, 8], a model is proposed to screen and inform the client about both the quantity and quality of the food. iLog collects data on the medical condition of an individual alongside the eating practices. Based on this information, it can classify normal-eating or stress-eating concerning every individual. The proposed iLog model is a learning model that can naturally recognize, order, and evaluate the food items from the plate of the client using a few sensors and camera images. It uses different state-of-the-art AI and machine learning models together with user feedback for refining the learning process. The iLog model can perform with a maximum accuracy of 98% with an average accuracy of 85.8% [8].

As user conditions and requirements keep changing with respect to time, the IoMT framework is also required to be flexible, dynamic, and adaptive to perform satisfactorily. Authors in paper [9] proposed an adaptive IoMT framework and separately test for people who are relatively less mobile and also in a situation where users are permitted to move freely. This proposed model also acts as an IoMT-based catastrophe rescuer wellbeing observing framework, which works as a rescue manager with a search facility in case of a debacle [9]. This framework is illustrated in Fig. 3.7.

3. Smartphone-based methods for infection detection

There are different means to detect coronavirus that includes clinical investigation of chest CT examination pictures and blood test results. The COVID-19 patient shows various symptoms like fever, sluggishness, and dry hack. Keeping this in view, a few
strategies can be adopted to develop a clinical recognition kit to identify the infection. However, these dedicated kits will be of prohibitive cost and convenience of use and acceptability by the users. Authors in paper [10] proposed an alternative system to detect COVID-19 infection using the smartphone sensors. This alternate proposition rightfully assumes that a majority of users and caregivers have smartphones for day-to-day activities. The same smartphone can additionally be utilized for infection identification purposes also. These days Smartphones are equipped with existing computation rich processors, large enough memory space, and a large number of sensors, including cameras, amplifiers, temperature sensors, inertial sensors, proximity sensors, movement detection sensors, and stickiness sensors. Using the sensors of the smartphones, an artificial intelligence (AI) empowered system is developed for signal processing and estimations, and the evaluation of the seriousness of pneumonia [10].

The smartphone’s reasonably accurate temperature sensor is used to measure the temperature of harmed tissues with its neighboring tissues to assess the difficult to recuperate wounds in patients with a diabetic foot ulcer (DFU) [11]. The change in heat conductivity estimated the tissues’ properties and can be utilized for the early detection of DFU. This model makes use of the smartphone temperature sensor to get self-appraisal by patients and self-check diabetic conditions [11]. Medical authorities in Tehran (Iran) classified the patients into three groups using AI-based reasoning and machine learning. Group-1 contains patients with aggravation. Group-2 contains patients with vascular inconveniences, and Group-3 includes patients who were figuring out how to control their glucose levels to an adequate level, as per their clinical records and data collected from their smartphone periodically. Besides, the tissue conditions of indoor patients are also considered in the computational model. The temperatures of the ulcer and adjoining tissues are continuously measured and communicated to the central server. The gathered information is utilized in a proposed model for detecting infections of human tissues [11].

4. IoT-enabled thermal screening for avoiding potential spread:

Thermal screening using thermal cameras or infrared thermometers are utilized at open areas to check the temperature level of individuals/groups to detect potentially infected persons and segregate them to avoid infection spreading. This approach is quite useful as it saves a lot of effort and time required to check each individual’s temperature using traditional contact-based temperature measurement systems. Most importantly, the chance of the person in charge of screening getting infected reduces significantly as the screening is done in a contactless manner. This principle is used in the proposed framework [12]. It utilizes keen head protectors with a mounted thermal imaging system to identify and recognize potential COVID-19 infected persons from the thermal image without human intervention. The thermal camera is located in the keen cap with IoT architecture that can continuously perform the screening procedure and update the information in the central server. The proposed framework is also integrated with the facial acknowledgment module to recognize the infected person.
This model is quite successful and popular among healthcare providers, administrators, and managers to manage and stop spreading the infection to a larger extent [12].

COVID-19 has put extraordinary pressure on the world’s health systems, exposes the populations’ vulnerability, and critically threatens the global communities in an unprecedented manner. Although efforts are underway for detecting the virus, providing treatments and developing vaccines, it is also critically important to leverage available technologies and innovate newer technologies to control disease emergence, arrest its spread, and especially develop disease prevention strategies. The objective is to review enabling technologies and systems with various application scenarios for handling the COVID-19 crisis. This brief will focus specifically on

- Wearable devices suitable for monitoring the vulnerable populations at risk of infection in general and those in quarantine, both for evaluating the health status of caregivers and management personnel and for facilitating processes for admission into hospitals.
- Unobtrusive sensing systems for detecting the disease and for monitoring patients with mild symptoms, whose clinical situation may worsen, and
- Remote monitoring and diagnosis of COVID-19 infection and similar diseases using telehealth technologies [13].

The focus of research groups, institutions, and technological companies

According to Forrester research [14], healthcare providers will be a great complement among IoT specialists once the interruptions brought about by the COVID-19 fade away. According to Achim Granzen, head investigator, Forrester research, just 7% of the work that significant IoT contribution is on smart healthcare [14]. Granzen also mentioned that this emergency has set off many thoughts and arrangements, and created an ideal opportunity to do more advanced studies on devices, methodology, and procedures. This will focus on governments, human services suppliers, healthcare providers, and administrators when the intense emergency is behind us. The work in this direction is already underway as the “drive-by” testing offices in South Korea, detecting and recognizing disease groups and contact tracing in Singapore.

Videoconferencing is playing an important role and currently pervasive, which assists with social separating while at the same time keeping organizations running and trying to do their usual business. We are experiencing a quicker adaptation in many different domains also. Schools are changing to video-classes, and even social occasions like marriages, family functions are broadcasted on the Web, and people prefer to participate remotely. Overall, the innovation is prepared and accessible to help fight this emergency and allowing work to be carried in a usual manner as far as practicable. Countries like Hong Kong and Singapore use this technology for travelers with a high probability of infection and monitoring those people on “stay home” notice.

Industry 4.0 drives abilities for remote tasks, checking and support of creation lines and assembling plants. This can have a fundamental influence on making producers in the Asia Pacific (APAC) stronger owing to the disturbances. A large portion of the
measures has been set up rather impromptu, similar to a Proof of Concept (PoC). A good part of those PoCs is expected to turn into well-performing products for crisis management situations. Ensuring human lives is the foremost priority in all emergency reactions and preparedness models. Government and private organizations are striving hard to leverage the experience gained from this COVID-19 pandemic.

**Effect of COVID-19 on IoT Activities**

There are both positive and negative effects on the IoT activities due to the current COVID pandemic. With the infection outbreak and spread, there is also a danger that current IoT activities are affected as the manufacturing pants are closed, expertise is under lockdown, and operational destinations are shut down. For example, the delay of the 2020 Olympics Games is a blow for IoT suppliers who have developed new IoT-based models that are to be utilized during the games. Many efforts and investments have been made by Japanese and many IoT-based organizations in building cutting-edge IoT innovations for intelligent transport management systems, providing world-class hospitality, monitoring wellbeing and health, monitoring the proceedings of the game, and many other things. The delay in Olympics games denies those organizations an opportunity to exhibit on the world’s most spectacular stage soon.

The world is also experiencing a surge in demand for newer use cases and applications in IoT domains during these unfortunate emergency circumstances like the COVID-19 emergency. Quickly, it adapted to the changing demands and responded well to the call by addressing the innovation bottlenecks, and limiting the computationally heavy and energy-hungry processes. IoT will continue to assume a significant role in modernizing human services and fiasco avoidance, open wellbeing, security, gracefully chain, assembling, and creation.”

Due to the stringent social distancing measures to control the spread of infection, organizations will robotize their procedures more in the coming months. Before this emergency, the use of robots was viewed as a threat to our jobs and employment opportunities. The current pandemic has changed the horizon, and the use of robots is seen as a prudent alternative to human-intensive tasks. Experts and business innovators are looking for answers to the questions like “in what manner would automation be able to quicken our recuperation and shield us from future pandemics?”. Robots working close by people in clinics to perform cleaning and mechanized distribution centers have very well demonstrated how people can be secured through computerization. Because of the severe effect of the emergency on flexible chains, the COVID-19 IoT effect prompts organizations to change their graceful chain procedures.

Numerous providers and organizations will reassess their single-provider and the single-nation policy that helps them reduce expenses when things are steady. The pandemic shows that it is excessively dangerous on occasions such as these to depend on one or barely any sources.
Healthcare is obviously at the center of the COVID-19 pandemic, and it is expected to experience a massive surge in demand. IoT MT is attracting a lot of attention, and researchers from different domains, including electronics, communication, computer science, and mechatronics, are coming together to deliver the best. AI-enabled edge devices with low-cost, low-power communication technology integrated with cloud computing are revolutionizing the healthcare landscape.

Capital Expenses (CAPEX) to Operating Expenses (OPEX) will be a new model. In a Q4/2019 IoT Analytics study of makers, 58% showed that they would want to acquire hardware as help or rent instead of keeping it on their asset report. Amid an emergency, this transformation of CAPEX to OPEX makes it a lot simpler for organizations to downsize their expenses as request vanishes.

Many advancements and innovations are now flooded to address individual’s and groups’ wellbeing with the outbreak of COVID-19. These advancements mainly incorporate:

- **Telehealth conferences.** Telehealth (where a specialist treats the patient through a video gathering and offers guidance) has emerged as a viable alternative. Both healthcare providers and healthcare seekers feel secured. For instance, the Stanford Children’s Health Hospital is currently experiencing many computerized visits each day.
- **Computerized diagnostics.** The natural next stage of telehealth is the use of sensors and IoT devices to perform computerized diagnostics. Clinics are exploring different avenues to explore this opportunity in this direction. Kinsa systems developed connected thermometers that are being used to control the spread in the USA.
- **Remote checking.** Remote checking and observing for providing assisted living to the senior citizens are experiencing a steep rise in demand. Livongo Health, a healthcare company, is focused on providing a line of products for remote IoT-based monitoring and management of “incessant sicknesses” to face the challenge arising from COVID-19 pandemic.
- **Robot help.** Many countries and especially in China, robots have been utilized to disinfect and clean emergency clinics and perform/remind medication schedules.
- **New uses for drones:** Drones and UA Vs are there for quite some time and companies, and specialists have been working to innovate many use cases. This COVID-19 pandemic has suddenly opened up new use cases like mass screening, ensuring social distancing, and contact tracing. The following is a set of examples of the use of drones for mitigating pandemic challenges.

1. **Clinical conveyances:** According to Zhao Liang, COO of Antwork, during the previous month, the automaton conveyance framework in Xinchang County has helped nearby emergency clinics for distributing drugs and clinical reports with the help of more than 300 drones during this pandemic situation.
2. **Surveillance and monitoring:** Many countries have utilized drones and UAVs to screen open spaces and large gathering successfully.
3. **Message and information dissemination:** Drones have been used to broadcast messages and spread awareness among citizens. Drones use alarm sirens to
alert a group of users violating social distancing norms. Drones are also used to communicate information periodically.

4. Disinfecting and splashing: Horticultural automaton company XAG Co. Ltd. automated disinfectant sprayers and splashing using drones in the last few months.

Many users require to track the vessels for efficient supply chain management, and it seems to quite useful and effective. The lockdowns have caused significant disturbances, and vessel tracking has become more meaningful. The company vessel-tracker tries to provide technological solutions to provide a framework integrated with effective GUIs to track vessels and make sense if a vessel is going to their destination port, or if there has been a significant change to its expected time of arrival (ETA).

Suppliers of IoT innovation are utilizing their information and refreshing people in general on what is happening in their systems. Vesseltracker.com, for instance, as of late distributed updates (in German) on worldwide voyage boats and cargo movement. Geotab can generate reports on the business street transportation movement across North America.

South Korea, which can script success stories about dealing with COVID-19 challenges, utilized its “Savvy City Data Hub” to permit epidemiological specialists to demand, acquire, and affirm information about coronavirus cases and contact tracing.

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