CHAPTER 5

Role of technology in COVID-19 pandemic

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5.1 Introduction

Pandemics leave a tremendous effect in our lives both socially and economically. Over the past hundred years, world has seen quite some deadly pandemics. Although, COVID-19 is the newest of its kind but relating to the past pandemics and how people benefited at that time by technology can be a great guide in current scenario. A few successful solutions deployed in past pandemics are discussed in this chapter.

Examining the technology and related systems that are helpful in the disease identification, limiting disease spread, and disease prevention is of paramount importance. Different new age technologies can be adopted by the government as an initial response strategy. This chapter mainly focuses on the use of the Internet of Things (IoT), Internet of Medical Things (IoMT), and other smart emerging technologies like drones, robots, autonomous vehicles (AVs), Bluetooth, and global positioning system (GPS), which can be helpful in handling this pandemic.

IoT is a promising technology of interconnected computing devices, transmitting data over the network without any human intervention. In the recent times, IoMT has captivated major attention from the field of healthcare. It is a blend of medical devices and software applications connected to healthcare IT systems.

In the current critical scenario of nCOVID-19, the most significant issue after the development of vaccine is an efficient way of reachability to the patients. This can be best done by using the concept of IoT.

Drones, robots, and AVs technology not only ensure minimum human interaction but also can be beneficial to access contagious COVID-19 patients. Wearables, making use of the Bluetooth and GPS technology, is another efficient way to monitor individual's health and their day-to-day stress levels in isolation. Altogether, these technologies can add a

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consequential share in the new paradigm of Tele Medicine, either for prevention of disease or identification and monitoring of the masses, paramedical staff, symptomatic, and asymptomatic COVID positives during the pandemic.

5.2 Technology and medical science

Medical science and technological innovation go together for a healthier future. Technology has made substantial and revolutionary contributions to the field of medical care, which has eventually helped in extending the life span of people throughout the world. Besides, it has also improved the quality of life by an efficient way of disease diagnosis and treatment. Thermometer, microscope, ophthalmoscope, stethoscope, laryngoscope, and X-ray are among the initial inventions in medical technology. Fig. 5.1 shows how the modernization in medical industry has been grouped [1].

As this chapter mainly focuses on the impact of technology in medical science, the below section describes the evolution of technology in healthcare.

5.2.1 Electrocardiography (EKG)

This technology benefits from the fact that an electric current exists in the heart, which allows it to be monitored with the help of an external device by the physicians. In electrocardiography (EKG), electrodes are attached on

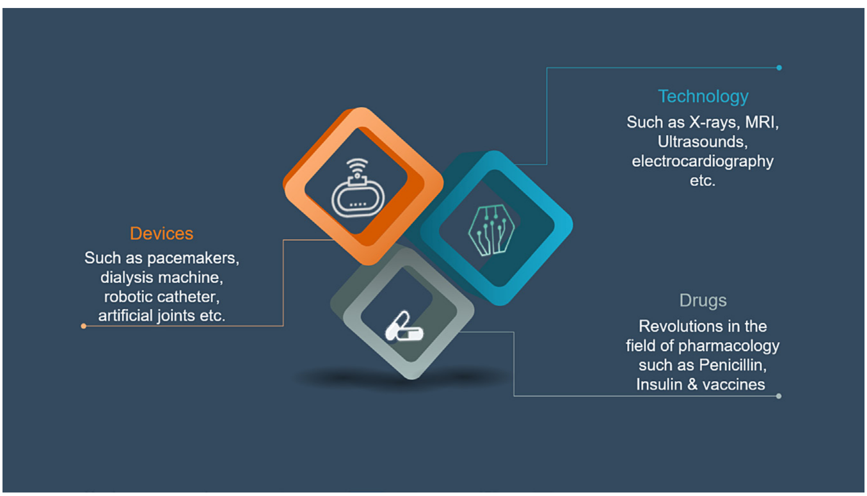

Figure 5.1 ***Modernization of medical industry.***

the skin externally, which monitors the electrical activity across the thorax. The result is known as an electrocardiogram [2].

5.2.2 X-ray

A German professor of Physics, Wilhelm Roentgen discovered a radiation, which could penetrate solid objects with a low density, and the resulting process could be seen on a fluorescent screen and recorded on a photographic film. This discovery aided the physicians to see the inside of human body and facilitate the process of disease diagnosis [3].

5.2.3 Ultrasound

An ultrasound yields the pictures of the inside body. It makes use of high-frequency sound waves. As ultrasound images are taken in real time, they can show the structure and movement of the organs.

5.2.4 MRI

This technology uses magnetic field and radio waves to picturize organs inside the body ensuring minimum damage. It is being used extensively for the detection of neurologic and musculoskeletal disorders and for the examination of cancer patients. MRI is superior to other imaging techniques as it can show problems that could not be seen otherwise [2].

In the recent times, technological and digital transformations have joined hands together for a healthier future. Some of the latest developments are remote consultations, telemedicine, targeted treatments, and healthcare mobile apps.

5.3 Past pandemics and technology

No doubt, current pandemic has changed the world totally. But unfortunately, a plethora of disease outbreaks and epidemics are observed in the last century. While corona viruses such as SARS-CoV and MERS-CoV have been responsible for a majority of these outbreaks, different types of influenza viruses, such as H1N1, H2N2, and H3N2, have been at the helm of all the four pandemics in the past years. The H1N1 further caused outbreak of two pandemics:

1. Spanish Flu of 1918–19
2. Swine Flu in 2009–10

While the H2N2 and H3N2 influenza viruses have been responsible for the Asian Flu of 1957–58, and the Hong Kong Flu of 1968–69, respectively [4] (Fig. 5.2)

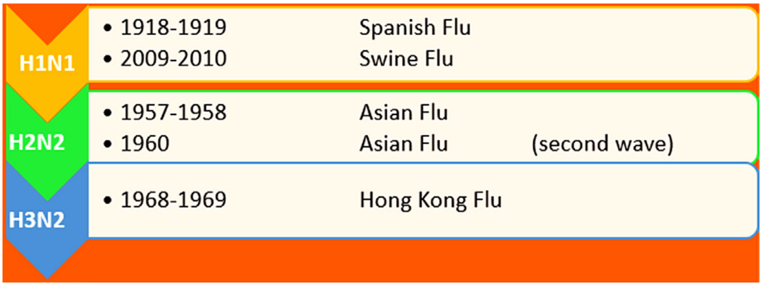

Figure 5.2 ***A view of past pandemics.***

Pandemics can cause serious threats locally and globally if not handled in time and wisely. Intensity of hazardous effects by pandemics varies among regions, proportional to the factor of population density. Disease outbreaks of avian flu, Asian flu, and Severe Acute Respiratory Syndrome (SARS) were raised from densely populated Asian-Pacific region. According to data collected from 2003 outbreak, SARS affected 29 countries, resulting in 8096 infections and 774 deaths [5].

5.3.1 Simulation models

Then the mobilization among people who are with close contact to each other is next factor that can result in uncontrolled diseases spread. Various simulation models were designed after 2003 SARS pandemic to closely predict different scenarios and disease spread among urban areas. Kwok-Leung Tsui and Zoie Shui-Yee Wong, with their coworkers, developed a simulation model that can evaluate an epidemic scenario influenced by intervention techniques and disease parameters [6].

5.3.2 Electronic surveillance system

During 1920s, a lot of work was done for the implementation of surveillance system for early detection of disease spread. Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE) is one such example. This surveillance system provides very early warning of unusual health conditions among entries using clinical and nonclinical data or more precisely any syndrome or untraditional health information [7].

5.3.3 Monitoring online search engines

The seasonal influenza disease's spread is of major concern in health sector. A new strain of influenza virus for which no immunity among people exists may result in pandemic with millions of fatalities [8]. This is why new versions of the vaccines are developed twice a year, as the influenza virus rapidly changes [9]. A way to do early detection of virus spread was proposed in 2009 by Jeremy Ginsberg and their colleagues. According to their work, early spread detection is possible by monitoring health-seeking behavior in the form of online search engine queries. These queries can reach huge number by millions of users around the world each day. The gathered data are then analyzed to track influenza-like illness in a population with large number of relevant Google search queries. But this approach can be applied in the areas where the population of web searchers is large.

5.4 Use of technology during COVID-19

5.4.1 Internet of Things (IoT) and Internet of Medical Things (IoMT)

IoT is also known as the Internet of Everything or the Industrial Internet. It is a new technology paradigm, which comprises a network with machines and devices that can efficiently interact with each other. IoT has gathered major attention from many industries all over the world and is expected to be an integral part of future technology [10].

IoT is becoming popular for many reasons. The most important reasons being the wide availability of broadband Internet, the reduced cost of hardware, and an enormous amount of people using smartphones, wearables capable of collecting data, and other "smart" products (Fig. 5.3).

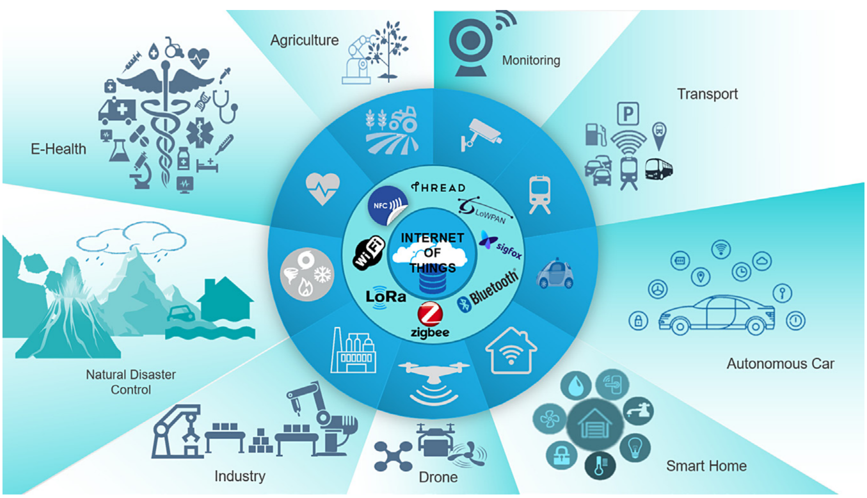

Figure 5.3 ***IoT in current era.***

IoT can possibly affect every single sector of our life. However, the fields that will be significantly affected by this technology include:

- Manufacturing and production.
- Health and medicine.
- Transportation.

This chapter highlights the use IoT in healthcare.

IoMT combines medical devices and applications to connect the information technology systems of healthcare by using various networking technologies. IoMT is making its place in society at a fast pace with a big percentage of global healthcare organizations already making use of it.

IoMT is a smart platform, which makes use of smart sensors, smart devices, and innovative communication protocols in order to examine the biomedical signals and subsequently diagnosing the disease of patients without much human involvement. Figure 5.4 shows a brief architecture of IoMT [11].

IoMT applications

IoMT may find its applications in the following:

- Remote monitoring of patients.
- Order tracking for medications.
- Transmitting the medical information monitored by the wearables to the concerned healthcare professionals [10].

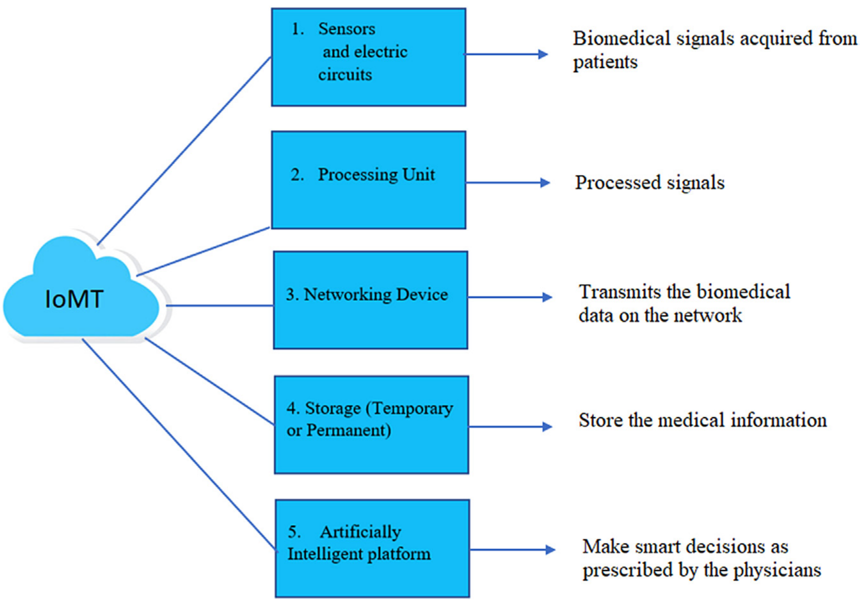

Figure 5.4 *Architecture of IoMT.*

5.4.1.1 IoMT device classification

IoMT devices can be classified as below:

5.4.1.1.1 Wearables

Wearables are further classified in to two categories:

1. Fitness wearables:These are the lifestyle devices, which are normally worn by the patients. Patient's health is monitored by collecting the data based on his physical activities by making use of built-in sensors. Some common examples of these wearables are bands, wrist watches, and necklaces (Fig. 5.5).
2. Clinical grade wearablesThis category includes the IoT devices, which have been certified and approved by the regulatory authority.These are mostly prescribed by doctors and used at a clinic or in home in order to

Figure 5.5 ***Fitness wearables.***

(A) Active protect (B) Qardio core

Figure 5.6 ***Clinical grade wearables.***

monitor and improve chronic conditions in specific diseases. Examples include smart belts (Active protect), which are especially designed to detect falls in elderly patients and chest straps (Qardio Core), which can record the ECG (Fig. 5.6).

5.4.1.1.2 Remote patient monitoring devices

Remote patient monitoring (RPM) has enabled the physicians to monitor and manage patients in a nontraditional manner. RPM collects the health data from individuals in one location, which can be a patient's home and then transmits this information electronically to healthcare providers who might be in a different location so that they can make their assessments and provide recommendations [12].

This approach saves time and provides services while ensuring patient's comfort. It can be used to send reminders and revised medical plans to patients based on their physical activities. According to IHS (Information Handling Services), more than four million patients will monitor their health conditions remotely by 2020. Some famous examples include remote blood sampling devices, continuous glucose monitoring device, and affordable surgical robots (Fig. 5.7).

Smart pills are also known as digital pills, which are equipped with ingestible electronic sensors in order to track patient's compliance with medication. They contain drug sensors that get activated on coming in contact with stomach acids and then send wireless message to devices like tablets, smartphones, or patches outside the body. Abilify MyCite is a popular example of a smart pill (Fig. 5.8).

5.4.1.1.3 Point-of-care devices

Point-of-care devices are diagnostic devices that can be found in doctors' offices, hospitals, and mostly in patients' home. They are used to acquire diagnostic results while they are with the patient or close to the patient. Common examples are devices used to test glucose and cholesterol levels,

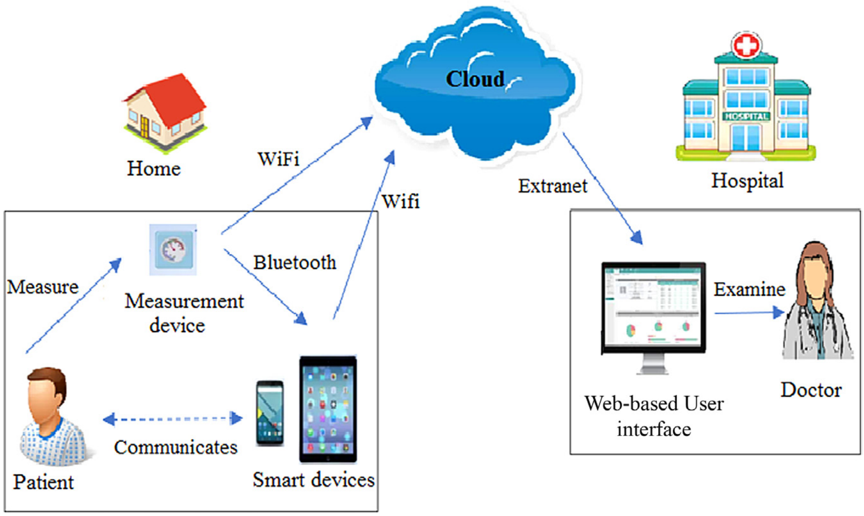

Figure 5.7 ***Remote patient monitoring architecture.*** *Image courtesy [13].*

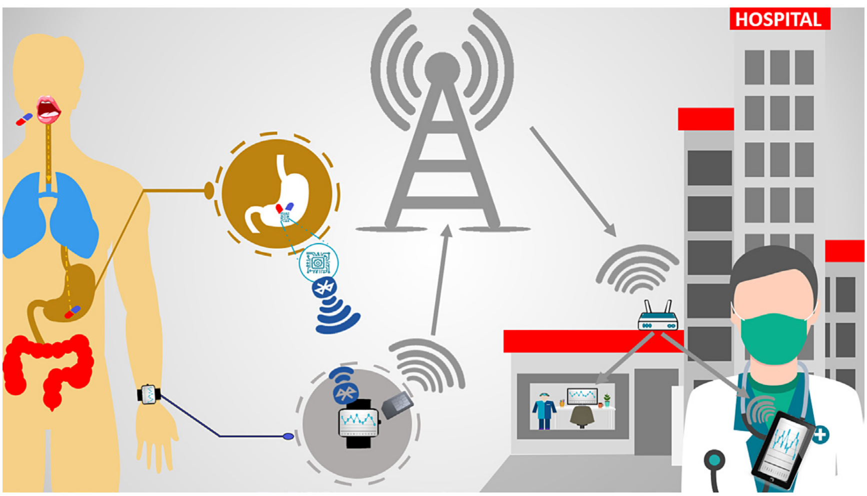

Figure 5.8 ***Deployment of smart pills [14].*** *Image courtesy [14].*

pregnancy testing, oximeter, tests for drugs of abuse, etc. The most prominent advantages of these devices include portability, convenience, and speed (Fig. 5.9).

5.4.1.2 Internet of Medical Things in COVID-19

The unprecedented outbreak of the novel coronavirus also known as COVID-19 poses a major global challenge. As the treatment of the disease

Figure 5.9 ***Point-of-care devices.***

Figure 5.10 ***A step-up process chart for using IoT during COVID-19 pandemic.***

is still under way, an optimal approach will be to find an efficient mechanism of disease diagnosis and management. A healthcare system capitalizing on the IoT can help achieve the utmost goal (Fig. 5.10).

5.4.1.2.1 Disease diagnosis

The standard testing method being used currently for COVID-19 screening is the reverse real-time PCR assay (rRT-PCR). It is a time-consuming, molecular-based test, which on the average needs 4–6 h to deliver the results. It also requires trained specialists and a well-resourced laboratory. This eventually puts a limit on the number of tests that can be conducted, which is not satisfactory in such critical circumstances. Hence, alternative rapid diagnostic tools are urgently needed.

In such a situation, a promising technique can be the point-of-care (POC) devices that employ lateral flow immunoassay (LFIA) technology to detect COVID-19 in human serum. This technology relies on the fact that after the COVID-19 infection, IgG and IgM antibodies against SARS-CoV-2 can be detected in human blood and their levels in the blood can offer an insight into the disease stage and its growth. With an increase in the number of cases worldwide, numerous POC LFIA devices have come to the front as rapid diagnostic tools [15].

5.4.1.2.2 Disease monitoring

In the current pandemic situation, the number of COVID-19 patients is increasing at an alarming rate, which calls for an efficient monitoring and surveillance system for impactful patient tracing.

IoT can play a vital role during this pandemic in context to contact tracing, cluster identification, and compliance of quarantine.

It is critically important to identify infected individuals in crowded places, which is being done mostly by using infrared thermometers. However, it does not seem to be much efficient as first, thermometer might not cover all the people in crowd and second, it might lead to the spread of virus as it has to be done by a health officer, who is examining many people standing in a queue and anyone among them can be infected. Hence, an alternative technology is required and IoT seems to be promising in this regard [16].

Following are some useful IoT technologies adapted for effective identification of patients:

1. **Smart thermometers:** Smart thermometers are medical thermometers that can transmit their readings to be collected, stored, and analyzed. These thermometers can be deployed in public areas to screen people with high fevers. As these are mostly linked to some mobile application, it allows them to be immediately transmitted their analysis to concerned establishments. Upon receiving, the establishment assimilates the data and produces maps on daily basis presenting regions facing an upsurge in high fevers in order to allow the authorities to locate potential hotspots.
2. **IoT buttons:** Hospitals themselves can pose many infection threats to the workers and the patients. In order to minimize these hospital-acquired infections (HAIs) and to ensure excellence in hygiene, numerous hospitals in Vancouver have installed IoT buttons, which are battery operated [4].

   These battery-operated buttons can be rapidly deployed in facilities of any size. They function to signal quick alerts to the supervisors so that they can be warned of any issues related to cleaning and maintenance as they can be a risk for public safety [17].

5.4.1.2.3 Disease management

With the rapid spread of COVID-19, the whole world has implemented strict lockdown measures to reduce the spread of disease. According to an estimate, approximately 10 billion people have been self-quarantined at

Figure 5.11 ***Use of IoMT for disease management.*** *Image courtesy [15].*

home. On the other hand, essential medical supplies and equipment have been on high demand. In order to seek medical help, the citizens, some of whom can be potential patients, must leave their homes, which contradicts the efforts being done for isolation and quarantine. Also, due to the lack of proper isolation wards, the health community has prompted the patients with minor or suspected symptoms to stay in their homes.

Additionally, the lack of isolation wards and proper medical devices has prompted the medical community to encourage those with mild or suspected symptoms to remain at home. In such critical situation, IoMT can be used as a medical podium not only to aid the affected individuals to get the suitable healthcare facilities at home but also to create an extensive disease management database for governments and healthcare organizations.

Fig. 5.11 shows such a platform where the process of disease management will follow the following sequence of steps:

- Individuals who are experiencing insignificant symptoms do not have to be in the hospital. Instead, they can acquire the diagnostic and healthcare requirements such as thermometers, masks, gloves, sanitizers, and POC kits used for detecting and monitoring COVID-19 and medications at their homes.

- Patients can then use the Internet in order to upload their regular health status to the IoMT platform from where their details will be broadcasted to the closest hospitals, Centre for disease control (CDC), and local health agencies.
- Hospitals can then provide consultations online depending on the health condition of every patient. Subsequently, the CDC and health agencies could assign equipment and places of quarantine, if needed.

IoMT platform has many advantages. It allows the disease status to be dynamically monitored by the patients and receive their medical requirements without transmitting the disease to others. Such a platform will also be less expensive and will offer more systematic database for efficient monitoring of virus spread [15].

5.4.2 Drone technology

A drone is an aircraft without a human pilot on board and a type of unmanned aerial vehicle (UAV). It has a ground-based controller, and a system of communications between the two. There are different ways to operate UAV flights:

1. Remote control by a human operator
2. Autonomously by onboard computers [18]
3. Piloted by an autonomous robot

UAVs in general and drones specifically were originally used for targeted missions that could be dangerous, risky, or trivial for humans. Sometimes, people misunderstand the terms UAV and autonomous drone and wrongfully use them for each other. Yes, many UAVs are automated as clear from its title, that is, they can achieve independent goals but still rely on human operators or some control. However, an autonomous drone itself is a UAV, but can operate without human intervention [19]. To make it clearer, these drones can take off, fly, complete the assigned target, and land completely at their own (autonomously). Hence, we can derive a statement from this discussion that UAV is not always an autonomous drone, but an autonomous drone is a category of UAVs.

So, in autonomous drones, any ground control system or communications management software plays an important role to carry out operations; thus, such drones are also considered part of UAS (Unmanned Aircraft System). To deploy such control, drones also employ host of advanced technologies such as cloud computing, computer vision, artificial intelligence, machine learning, deep learning, and thermal sensors [20].

Figure 5.12 ***A modern drone.***

The drones are mostly used in military applications, commercial purpose, scientific researches, agricultural field, medical (in current COVID-19 pandemic, which we will discuss in next section), and other applications [21] such as policing and surveillance usually in masses, aerial photography and drone racing as hobby, infrastructure inspections, and smuggling of prohibited goods and drugs (Fig. 5.12).

5.4.2.1 Versatility in drones

There is further classification of drones depending upon multiple factors; they are as follows:

1. **Structure**
   In this category, the classification of drones is done by the type of wings deployed or how the drone takeoffs, flies, or lands. The main classes differentiated by structural build are multirotor systems and fixed wings system. The third type is hybrid systems, which combine features of both multi-rotor and fizzed systems.
2. **Autonomous**
   Because of the absence of a pilot, drones always have a certain level of autonomy. An important distinction within the concept of autonomy is the difference between automatic and autonomous systems. In this category, we have different levels of autonomy by which drone is achieving its goals.
3. **Range/altitude**
   This category will differentiate drones from the range or altitude they can cover without any accident or defect.

4. **Size and weight**
   Other important characteristics of a drone are its size and weight. They can be categorized as nano, micro, mini, small, and tactical drones [22]. Clarke distinguishes large drones and small drones and divides the small drones in multiple subcategories [23]. The lower weight limit of large drones is 150 kg for fixed-wing drones and 100 kg for multirotor drones. Mini drones can vary in weight from several grams up to several kilograms. These mini drones are mainly suitable for indoor applications and recreational applications.
5. **Hobbyist**
   Such type of drones is just for hobby purpose and used at homes. These drones do not require any license to operate and are usually controlled by controller and fly with less precision.
6. **Weight of payload**
   The payload is extra function or feature added with drone to achieve the required goal. Sensors and cameras are most common payloads attached to any drone nowadays. Some drones can be used to transport parcels, drugs, goods, or any information between two destinations. All such loads can differentiate drones from each other.
7. **Energy Source**
   Drones run from energy source and serve different targets. The energy source selected to run any drone relies on difficulty level in achieving the required target. Also, the type of drone defined by characteristics discussed above can decide fuel type. The main energy sources that differentiate the drones are:
   a. traditional airplane fuel,
   b. battery cells,
   c. fuel cells, and
   d. solar cells.

5.4.2.2 Usability of drones during COVID-19 pandemic

The involvement of drones in military operations has increased since late 1990s. But civilian drones with commercial-grade low-cost technology are also getting popular and are already been used for various rescue tasks and natural disasters around the world. In this section, we will present the possible ways that can be helpful in fighting and disaster or disease spread specifically during COVID-19. The first country to face the wrath of COVID-19 has made great use of drone technology to counter its spread. Taking that as an inspiration, countries around the world have joined forces with numerous researchers and innovators in an attempt to find ingenious ways of using drones to fight any future or current pandemic at the best.

5.4.2.2.1 Drones as telemedicine and transfer units

Drones can be used to facilitate access to medical care in demoted communities. Demoted communities lack infrastructure and proper transportation. Therefore, drones are particularly helpful in such communities to help in the delivery of necessary health services and supplies in a time-effective manner. Drones travel faster than any manned vehicle and hence can overcome topographic challenges that would be very challenging to overcome by other forms of transportation.

As the person with COVID-19 is contagious, medicines and food can be transferred to the person in isolation. An example of autonomous drone is Beyond visual line of sight (BVLOS) [24]. These drones can fly far beyond visual line of sight while maximizing production, reducing costs and risks, and ensuring site safety and security, hence protecting the human workforce in times of a pandemic [25]. They can also be used for consumer-related missions like package delivery, as demonstrated by Amazon Prime Air, and critical deliveries of health supplies.

5.4.2.2.2 Drones for surveillance and screening

Drones with camera as payload are being used mainly for surveillance other than hobbyist photography. They can be ideal for crowd surveillance due to their feature to provide current location bird eye or aerial view in no time. That is why many countries around the world are deploying drones for crowd surveillance especially during COVID-19 pandemic.

Surveillance drones added with temperature sensor can updated about body temperature of peoples in any community area. Countries including China and India have also adopted the drone technology for crowd surveillance. The drones deployed are equipped with surveillance cameras that can effectively monitor sensitive areas in the city and allow the police to handle any unwarranted situation promptly.

5.4.2.2.3 Drones for public announcements

In addition to crowd surveillance, drones can prove to be highly useful for broadcasting important information, particularly in areas that lack open channels for communication. In California, Florida, and New Jersey, officials have used drones to get messages to homeless communities or notify and warn people about social distancing. The police authority in Madrid, Spain, used a drone equipped with a loudspeaker to inform people of the guidelines put in place regarding the state of emergency that was imposed [26].

European countries are also getting benefit from drones; many countries have deployed drones for making public announcements for public awareness during pandemics to stop spread of diseases [27] or disasters.

5.4.2.2.4 Drones for disinfecting places

Drone technology is benefiting people where there is need to avoid direct contact with viruses and bacteria. Using drones, disinfectants can be sprayed in contaminated areas. Increase of demand has been observed for spraying drones in agricultural lands during last decade. The Spanish military has recently adopted the use of agricultural drones made by DJI, a leading Chinese drone manufacturer, to spray disinfecting chemicals over public spaces [28]. On average, these spraying drones have a load capacity of 16 L and can disinfect one-tenth of a kilometer in an hour [27].

5.4.3 Robots

5.4.3.1 Usability in COVID-19 pandemic

Robots are smart machines and remained helpful during current COVID-19 pandemic. Robots can easily be deployed as frontline warrior in medical units due to less risk of contagious disease spread from the patients who are suffering.

Additionally, ultraviolet (UV) disinfection method (method to disinfect the areas from contagious diseases) is easily achieved with robots through preprogrammed procedures; hence, limiting the transfer of the disease via contaminated surfaces in hospitals or isolation centers. The autonomous disinfecting robots with very little or no human contact are recommended as compared to the manual decontamination, which involves the cleaning staff and may risk their lives [29].

Many countries all over the world took advantage from robot technology for not only mitigating the spread of COVID-19 disease but also for the sake of monitoring social and emotional health of patients and people in isolation. Other than the above-mentioned services, a few more helpful features of robots during the disaster are concluded below;

- **Delivery**: Robots are deployed during COVID-19 pandemic to deliver medicines, medical equipment, and serving food in medical units to avoid contact with patients directly, hence giving relief to medical staff. A Kerala-based Indian startup named Asimov Robotics has developed a three-wheeled robot that can be used to perform all these tasks while assisting patients in isolation wards [4].

- **Social distancing**: Robots with cameras are helpful to keep check in public, if social distancing is being followed or not. In addition, guiding public about preventive measures should be observed in public especially in affected areas.
- **Disinfecting**: As discussed earlier, robots are safer for disinfecting equipment and places of concern. A Danish robotics company has developed multiple disinfection robots, which disinfect effected area or equipment by UV light radiation. The UV rays tear apart strands of virus' DNA, hence making it harmless. The company named UVD has delivered its robots in China, healthcare markets in Europe, and United States. Their claim is that the robots can operate for about 2.5 h and disinfect about nine or ten rooms on a single charge [30].
- **Emotional support**: Many countries during pandemic underwent into strict lockdowns for months. Prolonged isolation affects mental health of people in negative way. Special robots are developed to share the emotions of people in isolation. These robots are virtually controlled by doctors to keep check of patient's health condition.
- **Medical procedures and surgeries**: The contagious nature of COVID-19 put many medical experts at added risk while performing regular procedures and surgeries. As the virus easily spreads through mouth and droplets, the dentist, oncologist, and ENT surgeons [31] stand at front of the danger zone. Although, general-purpose procedures were postponed during the pandemic by almost every country effected but still emergencies need special attention. Robotic surgeries are already being successfully done in different medical fields far before the pandemic crisis. Even with personal protective equipments (PPEs), physical distancing is the key to avoid virus spread. Consequently, during pandemic nonautonomous robots can prove to be safer alternative where close contact through patient's mouth and nasal cavity become necessity.

5.4.3.2 Robots replacing humans

Before we take a dive into the robot's history and their present-day prominence, it is significant to mention here a few statements defining robots.

Robot in Czech is a word for worker or servant. According to Robot Institute of America, a robot is, "A reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of variety of tasks.'. Similarly, by Merriam Webster Dictionary, robot is, "A machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)" [32]. According to Greg Freiherr, while science fiction robots have been capable of independent thought, emotions, even a little cooking and sewing, scientists are finding that endowing a mechanical being with even the most basic human functions is a monumental challenge.

In the mid-1900s, robots break into three categories, namely industrial, research, and educational. The first industrial robot, "Unimate" was developed in United States in 1954. George Devol, who coins the term Universal Automation, designed the very first programmable robot. He later shortens this to Unimation, which becomes the name of the first robot company in 1962 (Fig. 5.13).

Robot technology is maturing with time and in developed countries, large academic medical centers and health systems are the early adopters of robots. However, the increasing demand of robots indicates soon they will be found everywhere in abundance. Robots are designed to perform assigned tasks with high precision. They have extraordinary operational efficiency and are cost-effective. Normally, humans do work for their employers around 8–10 h at average. Robot has the ability to perform with efficiency rate almost three times greater (excluding one to two hours' time of charging) effectively than the capability of any human.

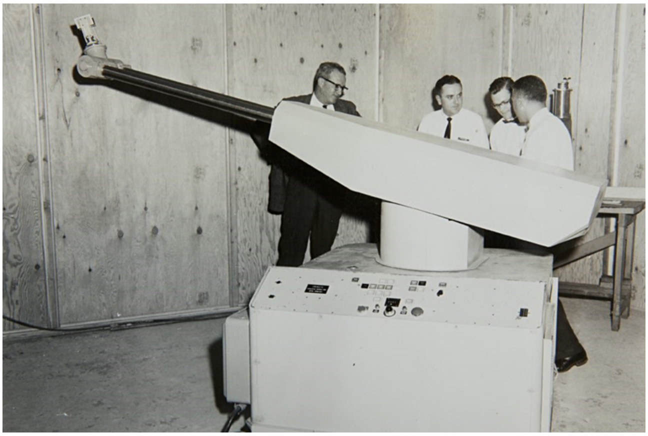

Figure 5.13 ***Devol, Engelberger, and their colleagues working on the development of the unimate.***

It is true; today, robots have replaced humans by way of performing precarious, detailed, and recurring tasks in various industries including agriculture, automobile, construction, entertainment, healthcare, laboratories, manufacturing, military, mining, transportation, warehouses, and law enforcement. The overview of different tasks done by them in industries is compiled below (Fig. 5.14).

5.4.3.3 Unmanned vehicles

Unmanned vehicles are without involvement of any human driver aboard. They can cover far-flung and difficult areas, impossible by any human driven vehicle. As compared to traditional vehicles, they have additional features of high safety, reliability, intelligence, and efficiency because of small size.

These vehicles can either be remote-controlled, remote-guided vehicles or autonomous, which are capable of sensing and navigating on their own. These autonomous driverless vehicles work according to the paths defined by installed sensors to sense surrounding environment or obstacles on the way with the help of intelligent software. The destination is fed by the software installed in these vehicles or at control station.

The vehicle and equipment that operate with little or no operator intervention are always an attraction because they save the labor cost in commercial areas and remove the direct involvement of operator specifically during dangerous applications. During the disaster or any global health crisis like COVID-19 pandemic, AVs can be of great help. They can ease the stress on existing delivery mechanisms while mitigating the spread of virus spread [33]. During 2016, a company JD.com, an e-commerce company, began testing the country's first developed self-driving vehicle for domestic usage. The other companies in market soon joined this race to compete each other. During the pandemic, China led the charge in the use of AVs. Beijing-headquartered White Rhino Auto Company, in alliance with UNIDO's Investment and Technology Promotion Office (ITPO), dispatched two autonomous delivery vehicles from Beijing to the Guanggu Field Hospital in the Hubei Province of China [34].

These UVs proved to be very useful during pandemic; hence, they can serve in various ways. These tasks may include delivering medical supplies within hospitals, distributing meals and medicines in isolation centers, on demand groceries delivery home-to-home during lockdowns, decontaminate infected surroundings, awareness announcements in large gatherings, and much more (Fig. 5.15).

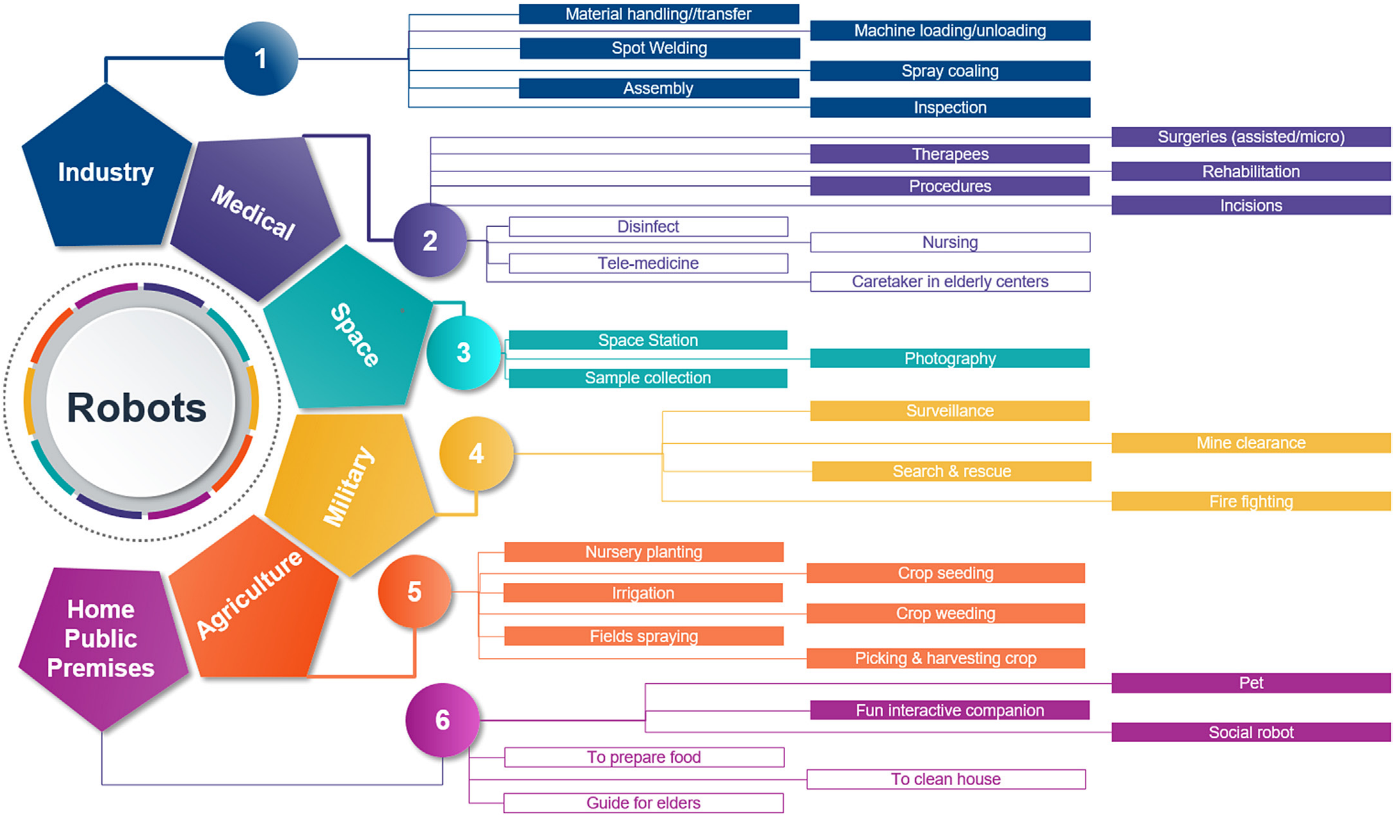

Figure 5.14 *Visual chart for robots in different fields and application.*

Figure 5.15 ***Unmanned Vehicle for delivery medicines and grocery, in China.***

5.4.4 Bluetooth and GPS technology

Bluetooth technology is a short-range technology that operates in UHF radio waves spectrum (ultra high frequency 300 MHz–3 GHz). Mainly, it is used to deploy low-cost, low-power, and short-time wireless connections between desktops, laptops, and Bluetooth devices like mobile phones, printers, digital cameras, headsets, keyboards, and even a computer mouse. This cutting-edge technology uses globally available radio frequency band between 2.402 and 2.480 GHz, which is dedicated for industrial, scientific, and medical use. In a nutshell, Bluetooth technology unplugs your digital peripherals and makes cable clutter a thing of the past [35].

The Bluetooth technology is very helpful for proximity calculation and preferred over other technologies because of its least invasive nature. With this technology, it is easy to monitor relative distance between two nodes without getting actual location of devices.

GPS is a navigation system that uses satellites to provide positioning, navigation, and timing (PNT) services to its users [36].

During COVID-19, governments can make use of the GPS technology for tracking the current and the historical location of positive patients. This will eventually help in backtracking other potential COVID-19 patients.

5.4.4.1 Applications of GPS

Some common uses of GPS during COVID-19 pandemic are:

1. **Mobile applications**:

During this deadly pandemic, many countries have released different versions of mobile applications leveraging GPS in order to identify the COVID-19 patients and help control the spread of virus. Most of these applications are downloadable for free using individuals' mobile numbers. Once launched, it will categorize the users as safe or unsafe using different criterions such as existence of virus symptoms, or international travel history. The GPS location of the suspected cell phone users will be stored in the database. This information can be later used for various purposes such as (1) to alert a safe user if he meets a suspected virus victim and (2) to send the GPS location of the victim to the healthcare officials if any emergency help is needed [4].

2. **Smart helmets**:
Many countries are making use of smart helmets equipped with built-in GPS modules, optical camera, and infrared thermal camera for screening the suspected COVID-19 carriers. The infrared camera scans the given area for any high temperature. Once an individual with a high temperature is detected, the optical camera captures the face of the suspected individual. The GPS module then determines the position coordinates and after tagging it, a notification is sent to assigned smart mobile through a GSM, which will be subsequently used for various purposes mentioned above [16].
3. **Smart ambulance system**:
Another efficient approach to combat the effects of COVID-19 can be the use of Smart Ambulance System, which is an integration of GPS and GSM. The GPS component is used to identify the location of the patient and the ambulance, whereas the GSM is used for data transmission. This system consists of an end-to-end smart health application. Once an emergency request is generated by a registered GSM mobile user facing extreme virus symptoms, such a system can track the location of the patient using the GPS embedded in the mobile, identify the nearest hospital with available beds, and urgently send them smart ambulances equipped with major requirements of a critical COVID-19 patient such as oxygen cylinder, oximeters, and other instruments for measuring the vitals. The timely delivery of patient to the hospital is extremely important. The ambulance is also equipped with (1) GPS module to determine updated ambulance location so that the paramedics can select the ambulances, which are already in the same route as the patient and for calculating the shortest/fastest possible route to the selected hospital; (2) GSM module in order to transmit any essential information to the

paramedics' database or the hospital. It will be even better if the time for patient's transportation can be utilized to gather major medical information about him/her and transmit it to the hospital using GSM in order to enable them to make prior emergency arrangements [37,38].

5.4.4.2 Asymptomatic and suspected patients tracking

Controlling the coronavirus spread is the key factor to mitigate COVID-19 disease. So far, many advancements and inventions in the technology have been done, in order to reduce direct virus exposure in societies, decontamination of suspected places, and effected surveillance of masses. Before looking further at possibilities to control virus spread, it is important to dig down to the level of coronavirus transmission biological details. The virus may enter the body through mouth, nose, and eyes, if a person with prior COVID-negative exposes to exhaled droplets of an infected person, touched the contaminated surface, aerosol, and possibly through fecal–oral contamination [39].

Here, we discuss all the possible transmission routes that may be cause of catching virus for a healthy person. Later on, these can be helpful in prevention of disease spread.

1. **Symptomatic transmission**: It is transmission of virus by getting in direct contact of a person having known symptoms of COVID-19.
2. **Presymptomatic transmission**: This is transmission by a person who is going to develop COVID-19 disease obvious symptoms. But at time of contact, both people are unaware of it.
3. **Asymptomatic transmission**: Some COVID positive patients develop delayed symptoms or none at all. Indication of being virus carrier is indicated by routine or follow-up checkups.
4. **Environmental transmission**: The transmission of disease can also occur via contaminated surfaces, and specifically in hidden way which in general could be unknown and typically not to be attributable to contact with the source.

5.4.4.2.1 Contact tracing

In all such cases, discussed before, prompt contact tracing can assuredly reduce the disease spread. By informing concerned authorities, which formerly contact without any hassle targeted people in need of quarantine or isolation.

Contact tracing mechanism is done on one suspected individual by strenuously tracing the infected person's footsteps, and later following up anyone with whom they may have crossed the paths. Many countries, badly affected by current pandemic, are spending millions of US dollars for deploying contact tracing network. Massachusetts recently allocated US$ 44 million to hire 1000, New York State announced it will hire 17,000, and California plans to hire as many as 20,000 contact tracers [39]. A few apps are developed while many are in testing phase, which could be helpful in tracing either asymptomatic or presymptomatic COVID positive patients.

Digital apps for contact tracing mostly use GPS and Bluetooth technology to trace contacts. GPS technology can give information of exact location for the concerned contact with correct time stamp, that is, what time person A was at location X. An example of such app deployed in Utah uses GPS [40]. If any person using that app is diagnosed with COVID-19, the concerned person guides them and asks to share the history of their locations during past days; it is usually the period of 14 days. After collection and compilation of location data, all the relevant people were informed to go in isolation in case of close contact. The app's cofounder and chief strategy officer, Jared Allgood made sure that the identity of patient remains hidden in all process.

Whereas, some apps which trace the contact with Bluetooth technology in smart phones collect data of close contacts that have been around near proximity during last 14 days (in case a person is tested COVID positive). Bluetooth technology is more reliable in contact tracing, as it will directly list down all those who got near to asymptotic or presymptomatic patient because of it short-range nature. But still one needs to keep on Bluetooth all time and only pairing is possible to those who also have Bluetooth in their smart phone turned on. Moreover, even if Bluetooth is on for both parties, it will not pair with the second party until both have close contact for few seconds. Hence, no data will be recorded of a COVID positive passer-by even with obvious symptoms (Fig. 5.16).

5.4.5 Telemedicine: a new era

A very recent development that is ushering in the field of medical science is telemedicine. Telemedicine refers to the practice of remote patient care when the healthcare provider and patient are not physically present with each other. It offers the following advantages:

1. With telemedicine, a patient can consult a specialist anywhere on the globe.
2. It reduces the workload of overburdened hospital staff.
3. In case of disease outbreaks, it lessens the chances of disease speed from the patient to the healthcare personnel.

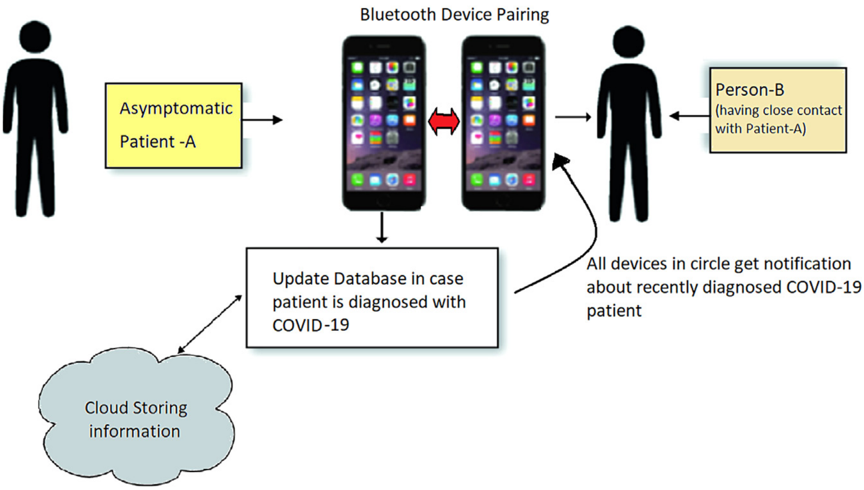

Figure 5.16 *Concept of contact tracing using Bluetooth technology.*

Figure 5.17 *Telemedicine, an integration of technologies.*

4. It can prove to be a lifesaver in emergency situations requiring immediate critical care.
5. From the perspective of patients, it means a shorter waiting time and hence a faster recovery.
6. It also enables people in rural parts of a country with unsatisfactory medical services have a quicker and easier access to healthcare.

Fig. 5.17 shows the basic idea of telemedicine. It is an integration of various technologies discussed above in order to make the healthcare facilities available at patient's doorstep.

5.5 Case study

Although many case studies can be quoted in the context of technology's use to combat COVID-19. The one mentioned below is a contact tracing mobile application using GPS in order to track the positive COVID-19 patients.

5.5.1 AAROGYA SETU app

As an attempt to minimize the spread of COVID-19, this contact tracing application has been developed by National Informatics Centre, which is a part of Ministry of Electronics and IT, India. The application can be downloaded by any Indian citizen for free and is available for both iOS and Android users. When launched, the application will enquire the users if they had a recent international travel history or if they are experiencing some symptoms of the disease. If none of these holds true, then the patient is said to be in green zone. A database will contain the list of all positive COVID-19 patients who are marked to be in the red zone.

This application integrates GPS location of the cell phone user with the Bluetooth technology to check if he has been exposed to a COVID-19 patient existing in the database.

If the individual in the green zone comes in close contact with another individual in the red zone, then the former will be alerted. In addition, he/she will also receive the guidelines to be followed and required relevant information. The application became extremely popular among the citizens and within first 5 days of its launch, 10 million downloads were recorded [4].

5.6 Conclusion

The current pandemic has drastically affected every aspect of our life. It has changed peoples' way of viewing different things. The whole world is on the lookout for best alternates of the available technological solutions. All the technologies discussed in this chapter are for prevention, mitigation, and restoration from aftermath of the disease spread.

IoMT has made a sizeable contribution in current pandemic. It is a promising technology that has shown potential in the collection, analysis, and effective transmission of health data to the concerned departments. Therefore, it is a choice of preference to be deployed for disease monitoring and management during this deadly pandemic. Drones have changed the entire concept of how things are delivered. Similarly, robots are replacing humans. UMVs are approaching to places where traditional man driven vehicles are unable to reach. Bluetooth and GPS are being deployed to look out for disease carriers in the surroundings.

IoMT, drones, and robots have joined hands together for the advancement of telemedicine field, which can be used for spreading limited clinical resources across a wide geographic area. It improves quality of care and access during the ongoing pandemic. All these technologies are on the way of maturing to help us fight against the deadliest pandemics.

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