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Smart epidemic tunnel: IoT-based sensor-fusion assistive technology for COVID-19 disinfection

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Abstract

Purpose – The purpose of the presented IoT based sensor-fusion assistive technology for COVID-19 disinfection termed as "Smart epidemic tunnel" is to protect an individual using an automatic sanitizer spray system equipped with a sanitizer sensing unit based on individual using an automatic sanitizer spray system equipped with a sanitizer sensing unit based on human motion detection.

Design/methodology/approach – The presented research work discusses a smart epidemic tunnel that can assist an individual in immediate disinfection from COVID-19 infections. The authors have presented a sensor-fusion-based automatic sanitizer tunnel that detects a human using an ultrasonic sensor from the height of 1.5 feet and disinfects him/her using the spread of a sanitizer spray. The presented smart tunnel operates using a solar cell during the day time and switched to a solar power-bank power mode during night timings using a light-dependent register sensing unit.

Findings – The investigation results validate the performance evaluation of the presented smart epidemic tunnel mechanism. The presented smart tunnel can prevent or disinfect an outsider who is entering a particular building or a premise from COVID-19 infection possibilities. Furthermore, it has also been observed that the presented sensor-fusion-based mechanism can disinfect a person in a time of span of just 10 s. The presented smart epidemic tunnel is embedded with an intelligent sanitizer sensing unit which stores the essential information in a cloud platform such as Google Fire-base. Thus, the proposed system favours society by saving time and helps in lowering the spread of coronavirus. It also provides daily, weekly and monthly reports of the counts of individuals, along with in-out timestamps and power usage reports.

Practical implications – The presented system has been designed and developed after the lock-down period to disinfect an individual from the possibility of COVID-19 infections.

Social implications – The presented smart epidemic tunnel reduced the possibility by disinfecting an outside individual/COVID-19 suspect from spreading the COVID-19 infections in a particular building or a premise.

Originality/value – The presented system is an original work done by all the authors which have been installed at the Symbiosis Institute of Technology premise and have undergone rigorous experimentation and testing by the authors and end-users.

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Paper type Research paper

1. Introduction

Currently, the entire world is threatened by COVID-19 epidemics. Looking at its speed of spread, many patients suffered, 84% of countries out of the total count around the world are affected [1–2]. Considering these facts, researchers are putting their efforts in analyzing COVID-19 by applying innovative methodologies. In recent times, governments of various counties have put numerous efforts for COVID-19 patients and arranged the required facilities such as hospital isolation beds, oxygen ventilators, N95 face-masks and face-shields [3]. In addition to this, the government is also spending lots of money on the testing of COVID-19 suspects and patients. In developing countries such as India, the government has distributed the whole country in various zones such as containment, based on the impact and the spread of coronavirus [4]. It has also been observed that various state governments and city councils are disinfecting various geographical regions or areas with a variety of insecticides, disinfectants and other alcohol-based chemicals. However, it has also been noticed that individuals are not following the framed rules by the government and frequently have been caught violating the health and safety rules. Such incidents have resulted in legal actions, financial penalties and police custody. Due to such circumstances, higher authorities of some of the countries have imposed strict lockdowns and executed awareness programs for society. Some of the health experts have predicted that the incline of coronavirus cases may continue until the end of December. They have also advised that the coronavirus vaccination and its clinical trials on humans are continued and may take a couple of months to provide good news in this regard. If the above problems will continue to persist, humankind may likely eye-witness a disastrous situation. For this purpose, a detailed and rigorous survey has been conducted to identify the research gap and provide a complete solution for the given problem. However, it is also a fact that any innovative systems will fail if it is not constructively accepted by society.

To resolve these issues, we have presented an IoT-based sensor-fusion assistive technology for COVID-19 disinfection, which is term as "smart epidemic tunnel" throughout this paper. The presented IoT-based sensor-fusion assistive technology (smart epidemic tunnel) will protect an individual using an automatic sanitizer spray system equipped with a sanitizer sensing unit based on human motion detection. The presented research work discusses a smart epidemic tunnel which can assist an individual in the disinfection from the possibility of COVID-19 infections. Furthermore, the smart epidemic tunnel is also equipped with an intelligent sanitizer sensing unit embedded with a NodeMCU controller, which stores the acquired human motion detection and in-out timestamp data on a cloud computing platform such as Google Firebase via message queuing telemetry transport (MQTT) broker architecture. It also facilitated the daily, weekly and monthly reporting of the total number of individuals passed through the tunnel with appropriate timestamps.

The presented article is organized as follows: Section 2 discussed the research work carried out by fellow researchers. Section 3 discussed the design and experimental setup, architecture design, sensing arrangements and the detailed workflow of the presented system.

2. Related work

Joshi (2020) has proposed a portable kiosk model which is designed based on the conducted CFD simulations. However, the proposed study represents a simulation-based approach which is very difficult to implement in real-time situations [5]. Maurya *et al.* (2020) have proposed a disinfection tunnel approach to protect society from external infections. However, the proposed system did not facilitate timestamp recording and cannot detect humans from a height of 1.5 feet [6]. Gupta *et al.* (2020) have proposed a system to maintain social distancing measures using ITS infrastructures for a smart city. The presented research work only discussed a proposal and future directions. It did not provide any of the amenities such as disinfection tunnel and sanitizer spray to protect the society from external infections [7]. Murthy (2020) has proposed a tiny sanitizer system for disinfecting passenger luggage. However, the system was not designed to disinfect humans. It also did not facilitate timestamp recording and the count of the number of people [8]. Kim and Lee (2020) have proposed a screening system to scan individuals who are suffering from fever or respiratory like illnesses. The proposed system was not designed to disinfect individuals externally [9]. Kwon *et al.* (2020) have proposed a drive-through screening system for the scanning of individuals to detect COVID-19 symptoms and collect the samples of individuals. However, the proposed system was not designed to disinfect COVID-19 individuals in a drive-thorough [10]. Qu *et al.* (2020) have proposed a system to protect CT equipment and radiographers from COVID-19 infection possibilities. However, the proposed system was not designed to disinfect radiographers externally using sanitizer like chemicals [11]. Liang (2020) has done a detailed survey of COVID-19 prevention methodologies and treatments. However, the proposed system was not designed to disinfect the people from the COVID-19 disinfections [12]. Poon *et al.* (2020) have proposed a gynecological scan system for COVID-19 patients. The system was also capable to perform obstetric scans and was designed to perform safety cleaning of medical equipment. However, it was not designed for the disinfection of humans [13]. El Majid *et al.* (2020) have proposed a preliminary design of wristband-like disinfection system to disinfect human hands. However, the proposed system did not facilitate to disinfect other parts of the body [14]. Takagi and Yagishita (2020) has carried a detailed discussion on the principles of safety and usage cautious usage of medical equipment. However, they did not propose any disinfection framework in the proposed research work [15]. Ahmad (2020) have proposed a standalone solar-powered mobile infected for disinfecting various things such as mobiles, keys, wallets, money and many more. However, they did not design this system for human disinfection purposes [16]. Dabh (2016) and Mohite *et al.* (2016) have tried to propose a unique geofencing based system to do real-time tracking of health patients. However, the system was not designed for the disinfection of health patients [17–18]. Lippi *et al.* (2020) have discussed various bio-safety measures to prevent clinical laboratories from COVID-19 infections. However, the proposed system did not discuss or present any disinfection-based approaches for humans [19].

3. Design and experimental setup

A smart epidemic tunnel is a customized solution designed to fight against the current pandemic situation and to disinfect individuals using an automatic sanitization spray. The presented system can be placed outside public places such as a hospital (especially in ICU for the safety of medical staff), vegetable markets, bus stop, airport, housing societies, railway station, industries, shopping mall, educational institute, post-office, bank, hotels and many more. Figure 1(a), 1(b), 1(c), 1(d) and 1(e) represents a design and experimental setup used in the conducted experiments such as a NodeMCU controller, an ultrasonic sensing unit, a light-dependent register (LDR) sensing unit, a solar cell, a

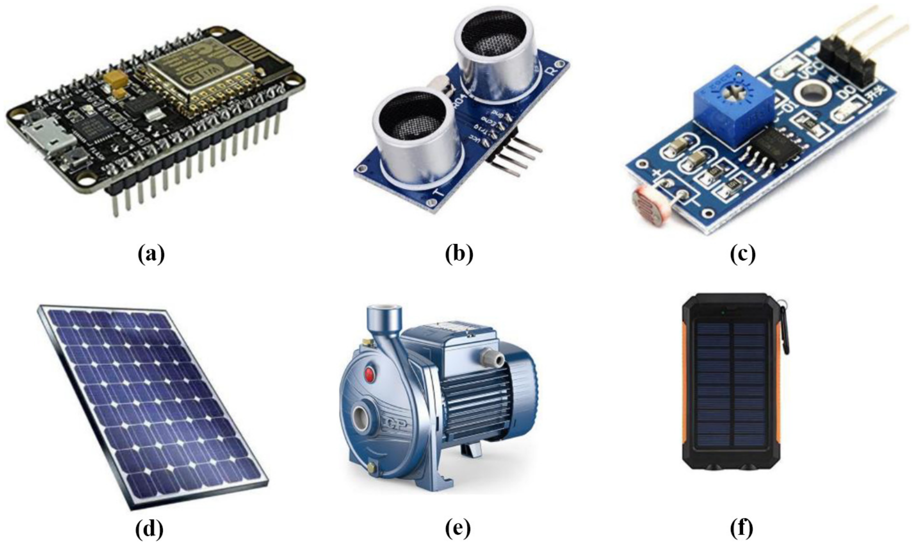

Figure 1.
Design and experimental setup of a smart epidemic tunnel

Notes: (a) a NodeMCU controller; (b) an ultrasonic sensing unit; (c) an LDR sensing unit; (d) a solar cell; (e) A O.25 HP booster pump; (f) a solar power bank

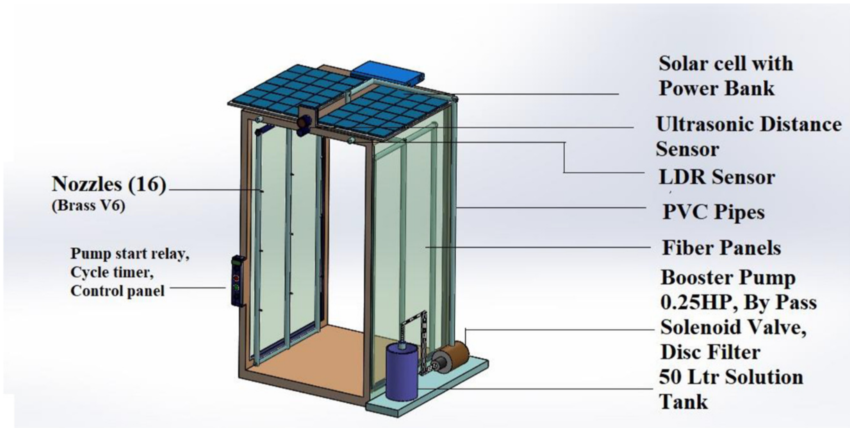

Figure 2.
A prototype design of a smart epidemic tunnel

0.25 HP booster pump and a solar power bank. Figure 2 represents a prototype design of the presented smart epidemic tunnel, and Figure 3 represents a detailed circuit design of the presented IoT-based sensor-fusion assistive technology for COVID-19 disinfection (smart epidemic tunnel).

4. The necessity of a smart epidemic tunnel

Recently, fellow researchers have made efforts in implementing a cost-effective pandemic tunnel to disinfect humans from COVID-19-like infections. In this study, an IoT-based

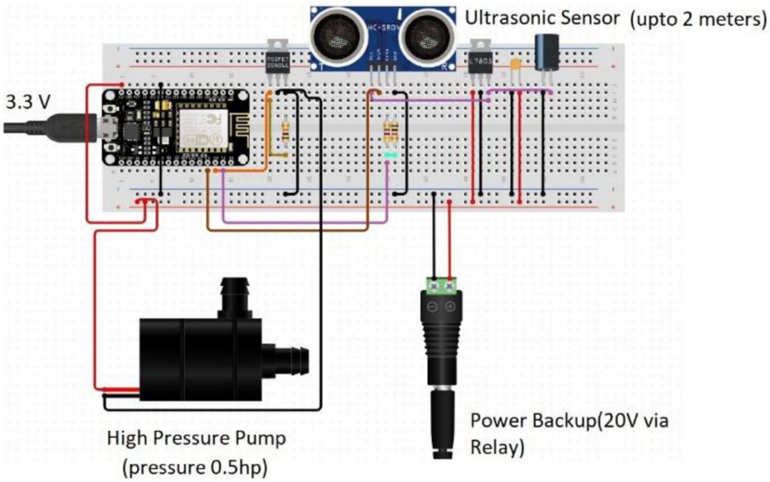

Figure 3.
A circuit design of a smart epidemic tunnel

sensor fusion assistive tunnel has been presented, which can disinfect an individual from the possibility of coronavirus infections. The major contributions of the presented PWP system are as follows:

- An IoT-based sensor fusion assistive framework has been proposed to do real-time detection of individuals from a height of 1.5 m. In the presented research work, a solar-powered epidemic tunnel has been presented, which has been installed and deployed at the entrance of the Symbiosis institute of technology, Pune.
- The presented smart tunnel can prevent or disinfect an outsider who is entering a particular building or a premise from COVID-19 infection possibilities. Furthermore, it has also been observed that the presented sensor-fusion based mechanism can disinfect a person in a time of span of just 10 s.
- The presented smart epidemic tunnel can function using solar energy during the day and it functions using a solar power bank at night time.
- In the end, web and mobile interface has been designed to provide daily, weekly and monthly reports of the counts of individuals, along with in-out timestamps and power usage reports.

The investigation results validate the performance evaluation of the presented smart epidemic tunnel mechanism. The presented smart epidemic tunnel is embedded with an intelligent sanitizer sensing unit which stores the essential information in a cloud platform such as Google Firebase. Thus, the proposed system favors society by saving time and helps in lowering the spread of coronavirus. It also provides daily, weekly and monthly reports of the counts of individuals, along with in-out timestamps and power usage reports.

5. Methodology

In the wake of the coronavirus outbreak, a sensor-based disinfectant tunnel has been designed and developed for the benefit of Symbiosis students, faculty and staff. It has been installed at the entrance of the Symbiosis Institute of Technology (academic buildings) to disinfecting the person passing through the academic buildings. It sprays a disinfectant that has the capability to kills 99.999% of viruses, bacteria, fungi, molds and spores within 10 s. This smart tunnel prevents further spread outspread of Covid19/SARS Cov-2. The area inside the tunnel is 3.28 m^2 (2 × 1.64 m) with a height of 2.5 m so that an individual can easily stand and rotate his body for disinfection. Pipelines fitted with V6 brass nozzles are installed inside the 1 cm dia PVC pipeline. A 0.25 HP pump and pressure control valve (manual) have been used to spray disinfectant solutions from the tank having a capacity of 50 liters. An audio-based proximity sensor with a buzzer and a relay circuit has been fixed to monitor the disinfection process automatically. The sensor mounted in the chamber detects the entry of a person and starts spraying a disinfectant solution for 10 s. The person is required to walk through the tunnel to the chambers' end. The minimum quantity required for a disinfectant per individual is 100 ml for 10 s which costs 0.10 INR per person. A tank of 500-liter capacity is used as a container for filling a disinfectant solution, i.e. sodium hypochloride. A total of nine foggers are fixed along the sidewalls and roof, to create a uniform misting condition inside the chamber. The water supply is pumped to the chamber through a filter using a 0.25 HP centrifugal pump. After exiting from the disinfectant tunnel, freshwater supply is also provided to the individual to wash their hands with soap. This system consists of two solar photovoltaic arrays of power output 200 Watts each. They are connected in a parallel arrangement, attached to PV inverter. PV inverter converts the variable DC output of PV arrays into stable AC. For increasing the voltage level and getting the better performance of the presented smart epidemic tunnel, a small transformer and MPPT have been used. Furthermore, a solar power bank is also used for storing solar energy which will be used by the proposed system at night.

5.1 The layered design of a smart epidemic tunnel

Figure 4 represents a layered design of the presented smart epidemic tunnel. It is an IoT-based sensor-fusion assistive technology designed for the safety of Symbiosis students, staff, workers and visitors. The detailed circuit design of the presented IoT-based sensor-fusion assistive technology for COVID-19 disinfection (smart epidemic tunnel). The presented layered design contains five layers:

(1) sensing layer;

(2) networking and communication layer;

(3) cloud service layer;

(4) data processing layer; and

(5) application layer.

5.1.1 Sensing layer. The sensing layer consists of a variety of sensing units such as ultrasonic sensing unit, LDR sensing unit modules, NodeMCU microcontroller unit and a 0.25 HP booster pump. Furthermore, this layer also contains a solar cell and a solar power bank. The sensing layer is responsible for detecting individual entering the smart epidemic tunnel and disinfect them using a sanitizer spray for 10 s. In addition to this, this layer consists of a solar cell that provides a solar energy-based power backup to all the sensing units and also operates a 0.25 HP booster pump in the day-time. At night time, the LDR sensing unit switches the smart epidemic tunnel in a solar power-bank based power mode. Again, in a day-time, the presented smart epidemic tunnel receives the required power from the solar cell.

5.1.2 Networking and communication layer. The networking and communication layer for establishing interfaces between a sensing layer, networking and communication layer, an MQTT broker architecture, Google Firebase and Web and mobile interfaces.

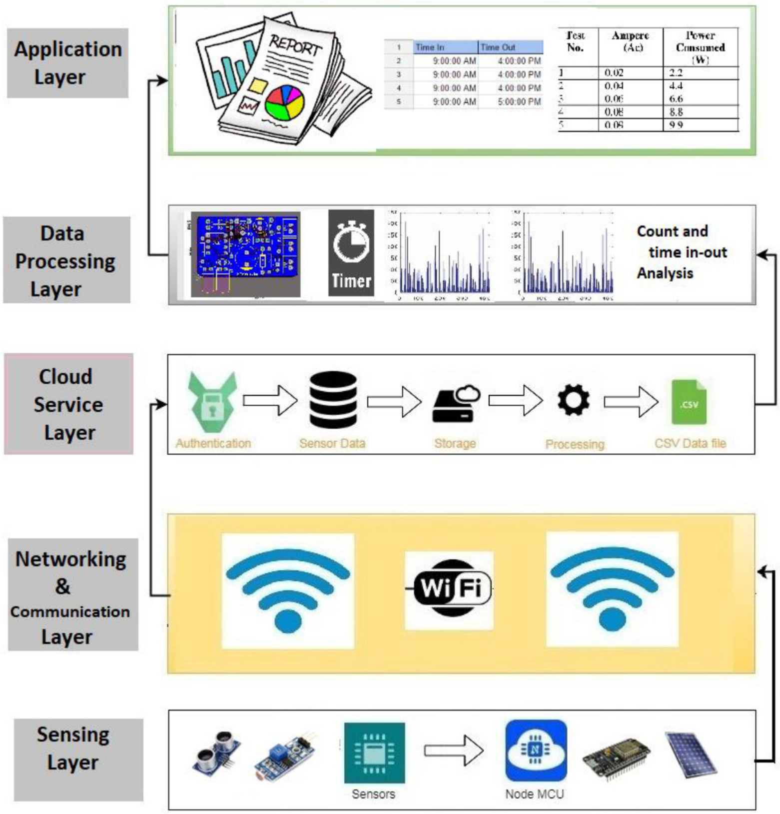

Figure 4. IoT-based sensor fusion system assistive layered design

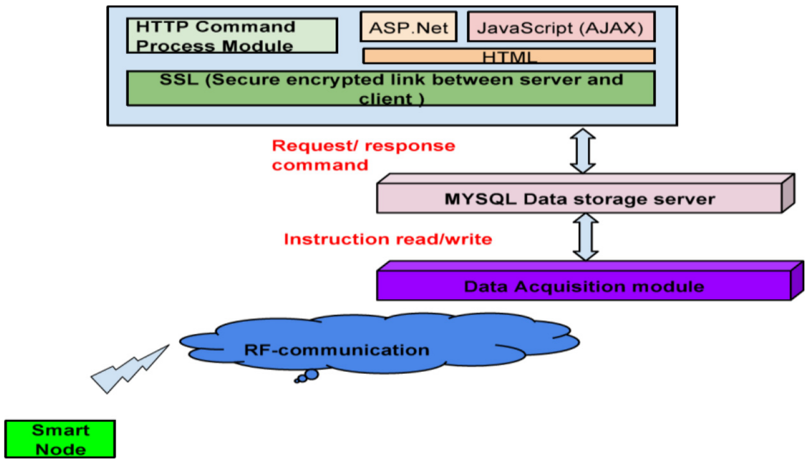

Figure 5. A back-end design of a smart epidemic tunnel

The MQTT protocol assists smart epidemic tunnel in transmitting the count of humans who have entered a tunnel through the day and night, along with their in-out timestamps on a Google Firebase database. Figure 5 represents a back-end design of a smart epidemic tunnel.

5.1.3 Cloud service layer. The cloud service layer is responsible for storing the in and out timestamp values of all the individuals who have entered the smart tunnel in the day and night timings. Furthermore, it also stores the counts of the number of individuals who have accessed tunnel in a particular building or a premise. The cloud platform used in the presented system is an open-source Google Firebase database.

5.1.4 Processing layer. The processing layer is responsible for fetching data from a Google Firebase cloud computing platform via an MQTT broker architecture and processes the received in and out time stamps values and the number of individuals who have entered the smart epidemic tunnel during day and night. This layer also generates a variety of daily, weekly and monthly reports which contain in and out timestamps and the counts of individuals who have accessed the tunnel. The processed data has been sent to the application layer for further analysis.

5.1.5 Application layer. The application layer consists of a graphical user interface (GUI)-based web and mobile interface which provides daily, weekly and monthly updates of the number of individuals who have accessed the smart epidemic tunnel during the day or night timings. The application also provides various graphical representations that can be forwarded to the security control room for further analysis.

5.2 The detailed working flow of the layered design of a smart epidemic tunnel

Figure 6 represents a detailed workflow of an IoT based sensor-fusion assistive system termed as "smart epidemic tunnel". The presented smart tunnel starts functioning when an individual enters the tunnel. Whenever an individual enters the presented smart epidemic tunnel, it sprays a sanitizer solution (made up from a mist of sodium hypochlorite) to disinfect an individual who is entering a particular building or a premise from the outside and might have been in contact with a COVID-19 suspect. Furthermore, the tunnel has been designed in such a way that it can also disinfect a disabled person sitting in a

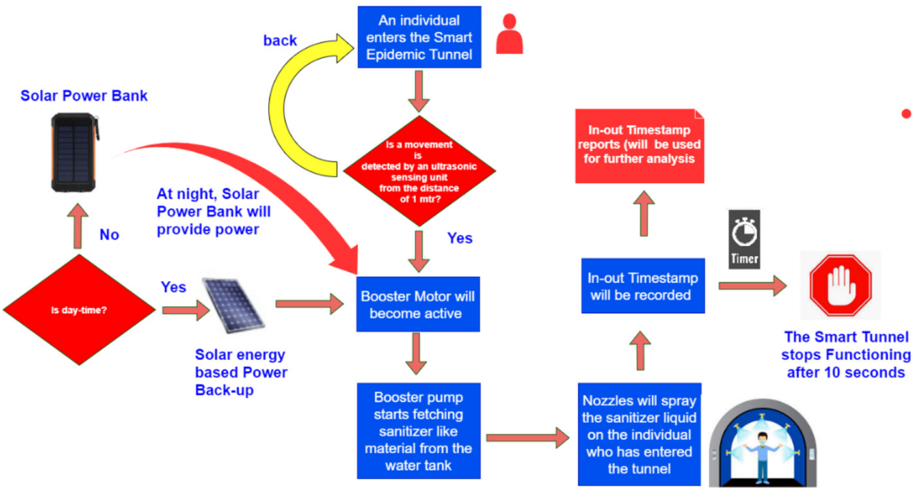

Figure 6.
A detailed work flow of a smart epidemic tunnel

wheelchair or a person riding a bike. Sodium hypochlorite is a widely used component of bleaches in a variety of cleaning solutions such as water purification systems. The presented system has been designed as per the requirement of Symbiosis Institute of Technology, Pune. However, the presented system is flexible enough to be upgraded in terms of its dimensions and size. The presented smart epidemic tunnel has been designed from portable structures, which are made up of PVC and steel materials. It can vary in dimensions and shape depending on site requirements and space constraints. Furthermore, it has also been observed that the presented sensor-fusion based mechanism can disinfect a person in a time of span of just 10 s.

The presented smart epidemic tunnel is embedded with ultrasonic and LDR sensing units which sense the number of individuals who have access to the smart epidemic tunnel during the day or night timings and stores the essential information on a cloud platform such as Google Firebase. The presented smart tunnel is a cost-effective alternative to disinfect humans from COVID-19-like infections.

5.3 The prototype design and deployment of a smart epidemic tunnel

A web and mobile interface of a smart epidemic tunnel. the detailed workflow of an IoT-based sensor-fusion assistive system termed as "smart epidemic tunnel". The presented smart tunnel is a cost-effective alternative to disinfect humans from COVID-19-like infections. Furthermore, the tunnel has been designed in such a way that it can also disinfect a disabled person sitting in a wheelchair or a person riding a bike. The presented system has been designed as per the requirement of Symbiosis Institute of Technology, Pune. The presented smart epidemic tunnel is flexible enough to be re-designed based on the requirements of a particular building or a premise. The presented smart epidemic tunnel has been designed from portable structures, which are made up of PVC and steel materials. The presented system can adjust in terms of its dimensions and shape depending on on-site requirements and space constraints. The investigation results have validated the performance evaluation of the presented smart tunnel. Based on the conducted experiments, it has also been observed that the

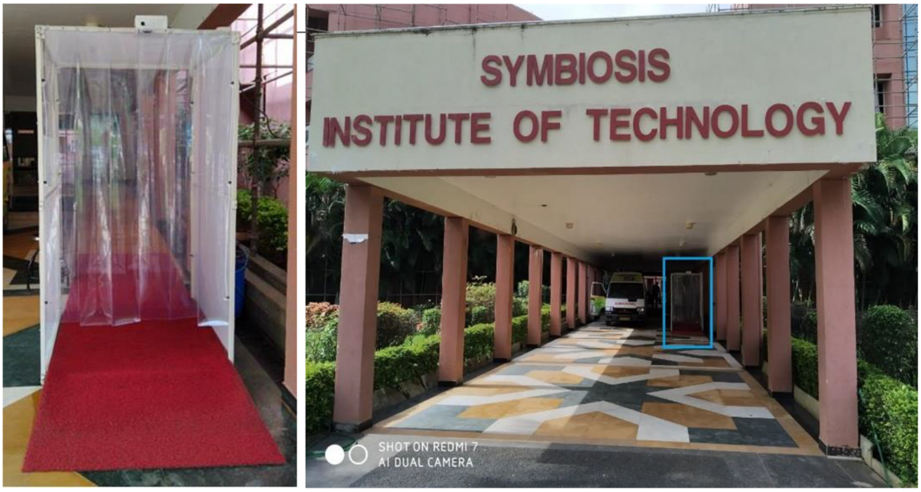

Plate 1.
A deployment of smart epidemic tunnel at The Symbiosis Institute of Technology, Pune

presented IoT-based sensor-fusion-based mechanism can disinfect a person in a time of span of just 10 s (Plate 1).

5.4 Web and mobile interface design of an IoT-based smart epidemic tunnel

Figure 7 represents a GUI-based Web and mobile interface design of an IoT-based sensor fusion assistive system. The presented interfaces present the daily, weekly and monthly reports of the counts of individuals, along with in-out timestamps fetched from the Google Firebase cloud computing platform. Furthermore, it also keeps the track of the consumed power and also provides information on power usage reports.

6. Conclusions and future enhancements

In the undertaken study, an IoT-based sensor fusion assistive framework has been proposed to do real-time detection of individuals from a distance of 1.5 m. The presented smart epidemic tunnel starts functioning when a human id detected by an ultrasonic sensing unit equipped in a tunnel. After an individual is detected, the nozzles placed in a tunnel spray a sanitizer solution (made up from a mist of sodium hypochlorite) to disinfect an individual who has entered the tunnel. Sodium hypochlorite is a widely used component of bleaches in a variety of cleaning solutions such as water purification systems. The presented system has been designed as per the requirement of Symbiosis Institute of Technology, Pune. The presented smart epidemic tunnel has been designed from portable structures, which are made up of PVC and steel materials.

The major findings of this study are as follow:

- The presented smart tunnel can prevent or disinfect an outsider who is entering a particular building or a premise from COVID-19 infection possibilities within 10 s.
- The presented smart epidemic tunnel can function using solar energy during the day, and it functions using a solar power bank at the night time. This functionality has been provided by an LDR sensing unit placed in a tunnel.
- Furthermore, the tunnel has been designed in such a way that it can also disinfect a disabled person sitting in a wheelchair or a person riding a bike.
- In the end, Web and mobile interface has been designed to provide daily, weekly and monthly reports of the counts of individuals, along with in-out timestamps and

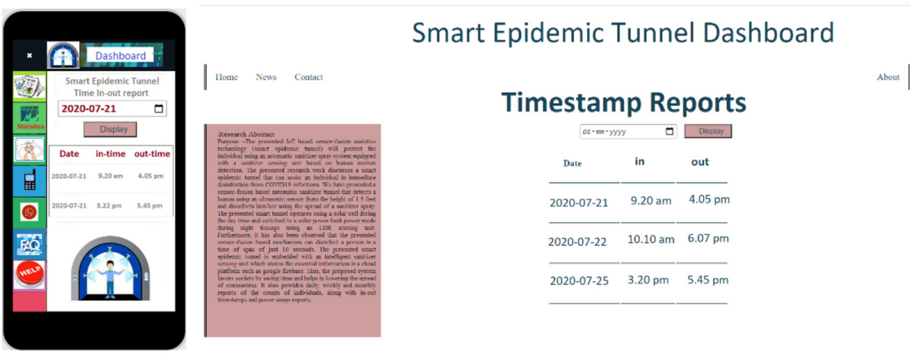

Figure 7.
Web and mobile interface design of a smart epidemic tunnel

power usage reports. In the future, an AI-based tunnel can be designed which can detect face-masks and provide auto-thermal scanning of the individuals to protect them from coronavirus like infections.

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