

Review

# IOT-Based Smart Helmet for COVID-19 Detection and Management

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## Article history

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**Abstract:** Covid-19 is one of the pandemics that has shocked the world. Having originated from China, the virus rapidly spread across many countries of the world. There was a need to come up with mechanisms to manage the spread of the virus. The traditional methods of temperature capture through thermal handheld gun thermometers were tedious and exposed the officers to the same virus. Therefore, due to technological advancement, the Internet of Things has been widely used with smart devices being developed. This study proposes an IoT-enabled smart helmet that scans individuals for high temperatures using a thermal camera, identifies individuals by capturing their images using an optical camera, and sends alerts and information to authorized officers' decision-making and further action. For instance, they would notify the identified individual and give guidelines on how to self-manage based on the COVID-19 management guidelines such as quarantine, exercise, self-distance, handwashing, sanitizing, and dietary needs. The integration of technologies in the smart helmet application is beneficial in addressing safety measures and enhanced healthcare and monitoring of patients. For instance, in crowded areas, manual testing can be challenging hence the need for a contactless screening. The implications in real-time data analysis, concurrency, Human-Computer Interaction, remote monitoring, data security, and interdisciplinary collaboration have enhanced operation and decision-making. The knowledge, once tested, will form the basis for advanced research and implementations in various domains such as manufacturing industries. The methodology involved data capture (input), processing, and output. Materials used include thermal and optical cameras for data input, GSM and Google location applications, Arduino IDE, and mobile phone applications. The study used simulation at a mall's entry point and captured the temperature of 8 individuals. Out of the 8 individuals, 3 had high temperatures whereas the rest registered normal temperatures. Temperature measurements were verified by healthcare personnel through a second measure of temperature.

**Keywords:** Smart Helmet, COVID-19 Management, IoT Platform, IMAGE Processing

## Introduction

In December 2019, the first case of the COVID-19 pandemic was reported in Wuhan, China. The virus has spread globally to more than 200 countries (Hageman, 2020). Other forms of Coronavirus include severe acute respiratory syndrome coronavirus (SARS-CoV) and the Middle East respiratory syndrome coronavirus (MERS-CoV) in 2002-2004 and 2012 respectively (Abeler *et al.*, 2020). The incubation period of coronavirus for its extremity is 1-14 days and symptoms include mild to moderate cough, fever, sore throat, sputum production, chills, and headache; or

severe (Shortness Of Breath) (SOB), myalgia, diarrhea, nasal congestion and conjunctival congestion; or critical Acute Respiratory Distress Syndrome (ARDS), secondary infection, acute heart injury and Multiple Organ Dysfunction Syndrome (MODS) (WHO, 2021). Also, persons of age above 60 years are at more risk due to underlying health conditions such as diabetes, asthma, hypertension, and heart conditions (Hageman, 2020).

The Covid-19 pandemic has resulted in a new normal in the day-to-day running of activities, ranging from businesses, offices, and social life. The pandemic posed a lot of challenges. These challenges include Pressure on

healthcare systems to fully accommodate the patients; rapid transmission rate leading to challenges in establishing control and management measures; reductions in economic gain due closure of businesses during lockdown; disruption of education when schools closed, increased mental health when families lost contact with their loved ones due to quarantine and cessation of movements; negative stereotype regarding the use of vaccines hindering wide acceptance of vaccine usage; loss of jobs and revenue due to travel restrictions on tourism leading to losses in tourism and hospitality industries; burnout amount healthcare personnel due to emotional and physical exhaustion; and high risk to vulnerable populations due to escalation of underlying illness (Maison *et al.*, 2021). Early detection and social distancing remedy such challenges by minimizing or avoiding their impact.

One of the remedies to combat its spread was to keep social distance from one another and limit contact to surfaces. According to Armitage and Nellums (2020), social distancing is the most efficient way to contain the spread of the virus. As a result, there was a need to develop a mechanism that would ease and make it effective to conduct operations. Chen *et al.* (2020) posit that human body temperature is an essential parameter in monitoring human health since it affects the body's metabolic processes. The monitoring can be done in real-time and accurately. Therefore, IoT has utilized this novel principle in determining differences in individuals' health. The IoT application can capture a large crowd at once and concurrently and provides for faster processing of data. Traditional methods for temperature measurement such as contact mercury thermometers are accurate but slow, inconvenient, and unsafe. Users need to measure the temperature of individuals one by one and are exposed to the risk of infection. According to Chen *et al.*, (2020), IRTs are convenient, safe, and fast, hence preferred in measuring body temperature. The safety approach is in terms of minimizing the contact between users and patients when detection is done at a distance. IoT is best described as the interconnection of physical objects with software and sensors to gather information and share it through a network without necessarily having human interaction.

### Objective

The emergence of Covid-19 has resulted in loss of lives and disrupted social interactions among people. As a result, there is a need to control and manage the spread of the virus since it spreads rapidly from one person to another. Efforts have been made such as the use of thermal screening at entry points into social and business places. However, this preventive measure is time-consuming and exposes the personnel carrying out the screening to the same virus. Therefore, there is a need to have a more efficient way of carrying out the screening at early stages

of infection. It is in this regard that we introduce a smart helmet that automatically detects the virus while ensuring social distancing.

### Related Work

IoT platforms could be used to remedy the spread of COVID-19 through early diagnosis, patient monitoring, workplace safety, quarantine monitoring, preventive alerts, contact tracing, smart metering, and fitness (Siddiqui *et al.*, 2021). Figure 1 summarizes the various application areas of IoT in managing the impact of the COVID-19 pandemic. These include early diagnosis of the virus, monitoring of patient's symptoms, ensuring workplace safety by preventing the spread of the virus to the uninfected, quarantine monitoring through mapping of the individuals, preventive alerts to warn people on visiting certain areas, contact tracing of infected individuals, smart metering and enhanced fitness and lifestyle to boost immunity to fight the virus (Nasajpour *et al.*, 2020).

Digital technology platforms such as Microsoft Teams and Zoom have been widely used by institutions to conduct meeting sessions, education, online work, and social connectivity with loved ones (Armitage and Nellums, 2020). Siddiqui *et al.* (2021) posit that IoT yields efficient services in terms of automation facilities and remote health monitoring thus promoting social distancing. Wearables and health monitors are part of IoT platforms that can be used to monitor and transmit patients' information in their environments to clinicians for evaluation, diagnosis, and treatment interventions, without necessarily visiting the hospital. This discourages the possibility of physical interactions. The delivery of medical supplies can be achieved through the use of telemedicine drones that are controlled through an IoT framework. According to Srinivas *et al.* (2022), IoT platforms control robots such as Autonomous Delivery Robots (ADRs) to deliver medical supplies and other items in locations that are not accessible by humans. During the Ebola pandemic, the US authority used non-invasive IRT to screen patients for signs of Ebola at the airports (Chen *et al.*, 2020).

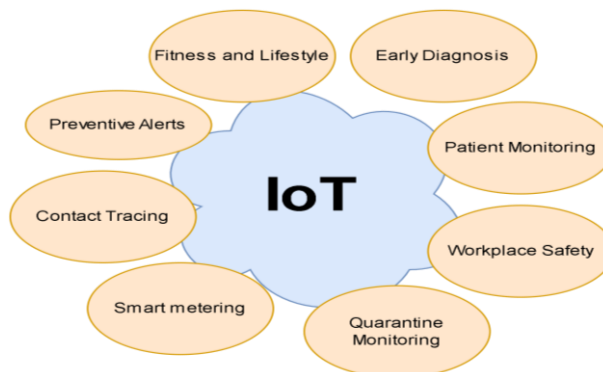


Fig. 1: Applications of IoT in Managing Impact of the COVID Pandemic

Goar *et al.* (2022) proposed an IoT-enabled smart mask to detect and identify individuals with high temperatures. The smart mask was fitted with a thermal camera, an optical camera, and a microcontroller processor. It was very effective to determine the temperatures of individuals and identify those who might have come in contact with an infected individual. However, users found it challenging to wear the mask for a long time due to sweating and limited air.

### Contribution

The main contributions of this study are as follows:

- a. The study supports the use of IoT in COVID-19 management through the smart helmet, limiting direct contact among parties
- b. The study shows how different modules can be integrated to come up with one unit which achieves a common goal
- c. It provides the basis from which future researchers can use in considering the use of smart helmets on robots in carrying out detection in domains rather than health

## Materials and Methods

This section will discuss the materials and methodology used in the smart helmet discussion.

Basically, the framework is composed of three segments, namely the input source which has a thermal camera, optical camera, and mobile phone app; a microcontroller processor that is integrated with Arduino IDE for coding purposes; and the output segment. The input segment performs the first functionality of the system. It detects the temperature and captures images of individuals through the use of thermal cameras and optical cameras respectively. The optical camera has an image processing functionality to determine the identity of an individual. Once the identity is identified, the data is transferred to the microcontroller which relays to the central database and system where the authorities sit for decision-making and further action.

Figure 2 shows the general infrastructure workflow of the system.

The system starts by scanning zones in a crowd or a congested area. This is done on the individuals within the crowd. Abnormal high temperatures trigger the camera to capture the faces of identified individuals within the crowd. However, if temperatures are normal, the system scans the crowd again until an abnormally high temperature is detected. After capturing the face, the GPS functionality is initiated to locate the exact position of the individual, and a notification is sent to the authority for further action.

### Thermal Camera

A thermal camera performs temperature screening of an individual. This camera captures an image using

Infrared (IR) waves and detects temperature abnormalities. The highest normal body temperature is 37°C thus body temperature above that triggers the sensors to generate IR spectra of high intensity (Irshad *et al.*, 2018). The camera is fitted at the front side of the helmet. This study suggests a CrowdTempPro T-500 model with the following specifications: Uncooled microbolometer sensor, 640×480 px resolution, <50 mK sensitivity, temperature measurement range of 30-45°C, ±0.3°C accuracy, measurement distance of 1-8 m and 45×35°C field view. Additionally, the camera should have the capability of performing multiple face detection of up to 30 people simultaneously.

### Optical Camera

The main aim of using an optical camera is to capture the image of an individual, which is used later for image processing that would identify the person. The camera also captures the containment zones hence giving authorities a clue in identifying red zones. The camera is fitted at the front side of the helmet. The following are the specifications for the optical camera to be used in the proposed study: 33 mm Full-frame CMOS sensor, 30 Mpx resolution, ISO range of 100-32000, DIGIC 8 image processor, simultaneous shooting speed of 10fps, dual pixels CMOS AF, Bluetooth and Wi-Fi enabled. Additionally, the camera should have an in-camera RAW conversion.

Figure 3 shows the basic positioning of the two cameras on the helmet. The thermal camera is fitted on the left side while the optical camera is fitted on the right side at the forehead position of the helmet. The helmet has a system controller which is the brain that integrates the functionalities of all the other components of the smart helmet. The helmet is made of elastic material which is light, ductile, and flexible.

### GSM and GPS Modules

A GSM is used to transmit notifications whenever there is a detection of a temperature that is higher than normal. A GPS is responsible for determining the geo-location of an individual by use of position coordinates after which the GSM sends a notification to relevant authorities (Ahlawat and Krishnamurthi, 2022).

### Data Transmission Protocol

Data transmission between the devices will be made possible using Wi-Fi protocols for data transmission. Wi-Fi allows the transfer of data over a wide range (Pahlavan and Krishnamurthy, 2020), hence most convenient for this type of technology. The system will use Wi-Fi to send alerts to authorities once a high temperature is detected and an image is captured and processed.

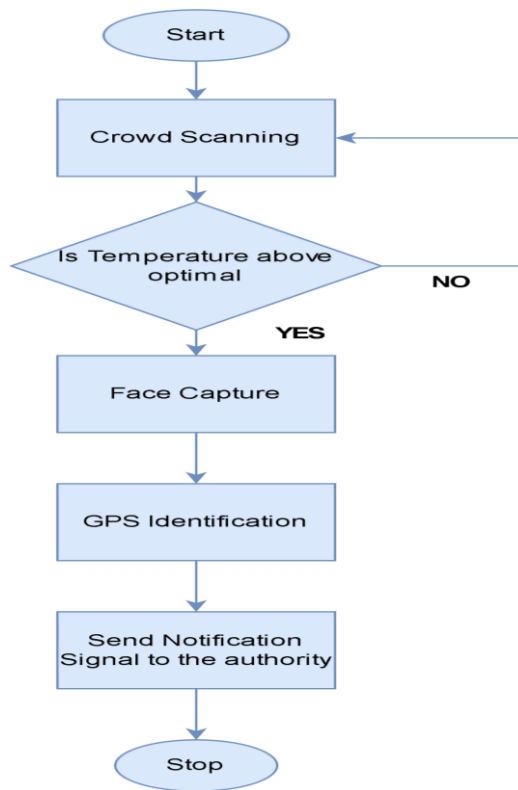


Fig. 2: General infrastructure workflow of the proposed system

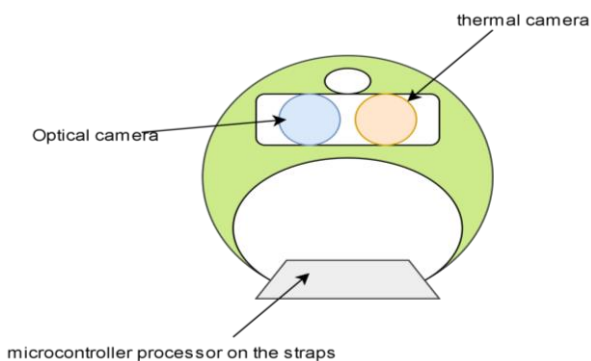


Fig. 3: Camera positioning on the helmet

### Arduino IDE

The Arduino integrated development environment consists of libraries, brace matching, syntax highlighting, and multiple file compilation for electronic communication and response (Ahlawat and Krishnamurthi, 2022).

### Google Location History

The system uses a Google location history to store the user's location based on the pattern of places visited. This data is handled by an individual's Google account where the location routine and mobility are monitored.

### Coding Practices

The priorities in coding practices will be to ensure efficiency, safety, and reliability. The coding practices for this novel system will involve the following. First, the coding for a smart helmet infrastructure is divided into modules including temperature detection, image processing, communication APIs, and the user interface of the system. Second, errors are handled through a robust error-handling framework whenever there are faults in the sensors and communication protocols. Third, the code, algorithms, and system usage are documented to provide further explanation regarding the system implementation. Fourth, tracking of code versions is done through Git for changes. Git enables the coding team to collaborate from whichever location they are. Fifth is the implementation of temperature detection algorithms using thermal sensors including setting thresholds and alert levels to detect temperatures above optimum. Sixth, choosing an image processing library. In this case, OpenCV will be used for image processing and analysis, using the Python Anaconda IDE. Seventh is implementing a data handling framework by using data structures that ensure maximum processing speed and memory minimization. Ninth, the user interface is designed to display the images and temperature analysis. The last coding practice is to implement proper communication protocols for data transmission such as the transmission of images and temperature alerts to the main system. The system should also be fitted with encryption protocols for data.

### Results and Discussion

The design is checked by carrying out a number of simulations to confirm its achievability. This is done through a model created by Proteus software where the testing phase is based on the logical interims to confirm the functionality and integration of the modules. Additionally, the testing is aimed at finding errors and whether the outcomes meet the set standards and user requirements. However, the testing is performed on each module separately before integration for testing the system as one. The simulation imitates the real performance of the real infrastructure. Figure 4 is an Arduino simulation prototype showing the three different flickering lights (red LED for high temperature, yellow for normal temperature, and green for low temperature).

Temperature above 37°C triggers the sensor to display red alerts, indicating high temperature. Therefore, the red Light light-emitting diode (LED) blinks. The yellow and green LEDs for normal and low temperatures respectively are kept inactive and only the red LED is allowed to display the signal. This is because the system is only mandated to show indications of high temperatures which are the basis for possible COVID-19 symptoms.

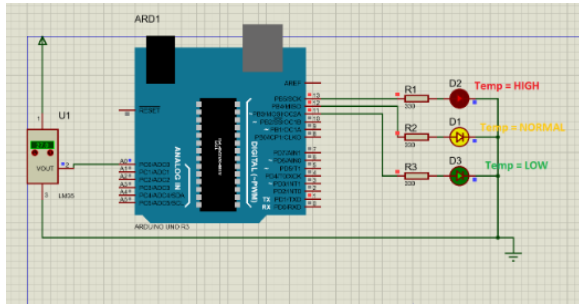


Fig. 4: Arduino simulation (microdigisoft.com, 2020)

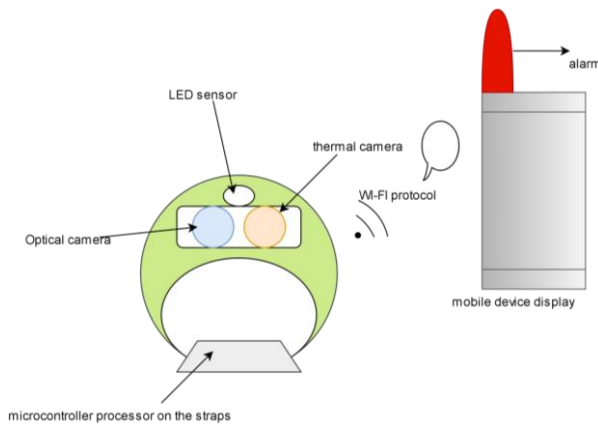


Fig. 5: Integrated system modules infrastructure

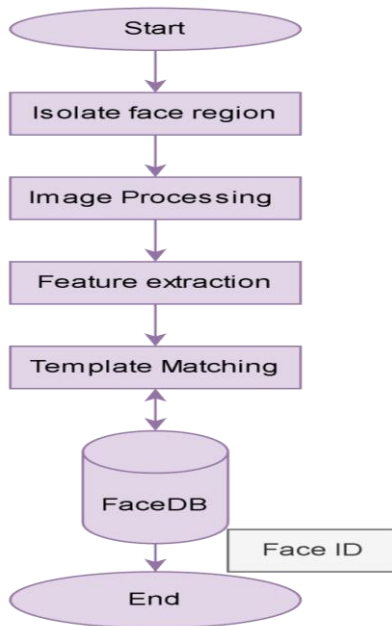


Fig. 6: Image processing and recognition data flow diagram using OpenCV

Upon identification of high fever in an individual, the GPS trackers determine the location, and the picture is taken by the optical camera and a wireless link sends

an alert to a mobile application. An individual is identified through image processing technologies on a centralized database.

Figure 5 shows the whole system architecture consisting of the smart helmet fitted with optical and thermal cameras and a sensor; a Wi-Fi protocol for communication; and a mobile device used as a display of results. The mobile device is fitted with an alarm to give alerts whenever an individual with a high temperature is identified.

Systematically, the Google location history of the individual is displayed on a mobile application based on his/her Google account information for mobility and other information regarding behavior. The locations are mapped by the officers upon which decisions are made on tracing the contacts of the individual. The image is captured using the optical camera and relayed in the system for imaging processing using OpenCV libraries that are used for image processing and identification. It is fed into the central database to find if there is a match for the image, whenever a match is found, it is given an ID with all details relevant to the person.

Figure 6 shows the general stages of face recognition using OpenCV. First, the image is captured and fed into the system. Only the face region is captured and image processing is performed. The key identifiable features such as the eye region are extracted from the face to pass through the face database for template matching. Template matching involves comparing the features with those existing in the database to find out whether there is a match. Once a match is found, the face is given a face ID as a unique key identifier.

Once an individual is identified, an officer would send a notification by giving COVID-19 management measures such as self-quarantine, social distancing, taking plenty of water, physical exercise, and immune boosters. Also, they are advised to seek further medical assistance whenever there are other complications that are beyond self-quarantine and that need medical attention, therefore attending to an individual without necessarily interacting with them.

The prototype was tested at a mall's entry point where a security personnel wears a helmet facing the crowd entering the premises. The crowd was scanned to determine the temperature differences among the crowd. 8 individuals were included in the simulation, who gave the following results:

- Person 1: 36.7°C
- Person 2: 38.1°C
- Person 3: 38.3°C
- Person 4: 37.1°C
- Person 5: 37.0°C
- Person 6: 38.3°C
- Person 7: 36.5°C
- Person 8: 36.9°C



The sensors only trigger alerts for temperatures way above 37°C. Person 1, 4, 5, 7 and 8 have normal body temperature whereas Person 2, 3 and 6 have elevated body temperatures. Therefore, the system alerts Person 2, 3 and 6 by flickering a red light, and their respective images are captured. The GPS is initiated through a mobile device and data is displayed on the screen of the device displaying the temperature, image, and location of the patient. Upon identification, contact tracing is done and individuals are notified, medical personnel perform a second measure of the temperature using an axillary glass mercury thermometer to verify its correctness. The average variations in temperature for the individuals were found to be  $\pm 2^\circ\text{C}$ . This confirms the effectiveness of the proposed system in detecting high temperatures for COVID-19 patients.

In an experiment, comparing the performance of an IRT forehead thermometer with an axillary glass mercury thermometer, it was discovered that the temperature differences were insignificant (Chen *et al.*, 2020). However, other researchers found a significant difference between the IRT thermometer and contact-type measurement. For instance, a difference of  $+58^\circ\text{C}$  is a huge difference, therefore the two thermometers could not be used interchangeably (Chen *et al.*, 2020).

### *Thermal Imaging Algorithm*

In using IR thermography to scan and capture the temperature of an individual, the smart helmet's thermal camera focuses on the forehead. According to (Irshad *et al.*, 2018), thermal radiation is emitted whenever the temperature of an individual is above absolute zero. The IR camera detects the electromagnetic spectrum in the radiations, which are emitted within the IR range. Temperature difference is determined by measuring the heat intensity. High intensity translates to a higher temperature above the normal temperature (Irshad *et al.*, 2018).

### *User Experience and Acceptance*

Generally, the implementation of the smart helmet was widely accepted by users due to several reasons including minimization of contact distance with the crowd and reducing panic among people as opposed to handheld forehead IRTs. However, users noted some drawbacks of the proposed system. These challenges included abstractions along the path which interfered with the scanning and image capturing; the inability to capture individuals wearing head gear; challenges in isolating individuals suspected to have COVID-19; and positioning of the helmet where some individuals were tall. Consequently, the challenges were minimized by standing on high grounds to capture all individuals regardless of their height and where there were obstructions and having a communication mechanism to affected individuals by

notifying them and linking with medical personnel for further action.

## **Conclusion**

The COVID-19 pandemic resulted in countries coming up with mechanisms for managing and controlling its spread. This could not have been successful without the use of technology, preferably the IoT. This research has used an IoT-based smart helmet as a measure to detect and support decision-making for COVID-19 management. The study has evaluated the efficacy of the smart helmet in detecting high temperatures as a symptom of COVID-19 infection among a large crowd simultaneously. From the results, it is evident that the application is accurate, fast, and convenient. Also, it minimizes physical contact with patients, enhances early detection and contact tracing, and reduces stress on healthcare facilities due to its remote use, integrated technologies, and non-contact nature.

### *Limitations of the Study*

- The advanced technology incorporated in the smart helmet may be expensive hence limiting the widespread adoption of the technology
- Fatigue and discomfort among the users due to increased weight of the components when used for a longer duration
- The cameras might have a limited field of view hence limiting the capturing of some fine details or all individuals that need to be scanned
- Ethical issues and privacy concerns may arise regarding the consent of individuals in scanning and sharing data
- The research is constrained to a moving crowd, especially at exit and entry points
- There are potential areas that need improvement, these include using materials that are lighter, stretchable, and flexible (Su *et al.*, 2020), using cameras with wide field of view, encryption of data, and establishing a framework for ethical and privacy concerns

### *Future Recommendations*

More research needs to be done to determine the most efficient technologies that are more portable and with limited user engagement. Also, the technology would be beneficial when installed along cities for an enhanced smart city and ensure that people are aware of the existence of such technologies through civic education.

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## Ethics

This article is original and contains unpublished material. The author declares no conflict of interest. The study was committed to ensuring the utmost integrity, protection of rights, well-being, anonymity, and privacy of the collected data.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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