Chapter 4
Advances in Sensor Technology and IoT Framework to Mitigate COVID-19 Challenges

Introduction

The backbone of an IoT system consists of sensor networks that can recognize the hints of COVID-19. Upon identification, an area could be “secured” to restrict spread and guarantee brief treatment to contaminated people. It is not very difficult to envision such frameworks being fused into future smart city arrangements, which now incorporate applications planned for improving wellbeing with the help of an IoT theme.

IoT, along with the advancements in wireless communications, cloud technologies, and artificial intelligence (AI), has been in use for a comprehensive set of applications during the COVID-19 crisis. The low energy consumption, the network of short-distance communications technologies, and industry startups are re-engineered to design, develop, and prototype low-cost IoT smart sensing systems to assist, collaborate, and mitigate the global COVID-19 pandemic [1].

A few IoT and sensor-based systems in the forefront and are used to mitigate COVID-19 challenges are discussed in the following sections.

System for Avoiding Face Touch

Scientists at Media Lab, Massuehcest Institute of Technology (MIT), USA [2], have been developing a device to alert users against touching their faces. It is a seemingly simple device that works on the principle of wireless communication, magnetic flux detection, and machine learning integrated with artificial intelligence techniques. Since coronaviruses survive for days on many surfaces, a person can get COVID-19 by touching a contaminated surface or object and then touching their mouth, nose, or eyes. Face touching in a subconscious mind is quite natural among human beings, and quitting this habit is far easier said than done. Most people touch their face...
Advances in Sensor Technology and IoT Framework …

frequently throughout the day, usually without realizing it. It is a hard habit to break and requires much conscious effort. This habit is more severe in the case of kids and more in school going kids.

The MIT Media Lab has come out with a technology called “Saving Face” [2]. It is a suite of easily scalable technologies to alert people when they are about to touch their faces and, in turn, help them to fight the pandemic.

Researchers from the Media Lab community came up with three classes of sensing technologies capable of detecting hand-face proximity and alerting the wearer. The device has two modes of operation, namely “record mode” and “alert mode.” In “record” mode, users can train themselves to break the frequent face touch habit by learning how often they touch their faces, while “alert” mode will directly warn them with an alarm or vibration whenever they attempt to touch their face [2].

The Design Approach of the “Face Touch” Detection System

Include

1. Using a SONAR-inspired approach to measure the distance between hands and face and warning the user with an alarm when they get too close. This technique transmits an ultrasound signal from earbuds and receives it with a microphone attached to the earphone near the face (neck). Many inexpensive off-the-shelf wired earbuds can generate and detect 20 kHz ultrasonic frequencies. In principle, users can use this approach with a smartphone for less than US $5 in headphones and cables. A mobile app offering both record and alert modes has been developed for the purpose. The open-source alpha version is available in Github (https://github.com/camilorq/SavingFaceApp) [2].

2. The second approach is based on the principle of magnetic flux change and detection. A device (https://github.com/irmandyw/magsense) has been developed that vibrates when the hand and face get too close. The device consists of a transmitter ring or bracelet fitted with a tiny magnet, which creates a magnetic flux. A receiving sensor (magnetometer), along with a controller embedded with the necessary code, is developed as a wearable device around the face as a necklace or a clip-on. Whenever the hand comes closer to the face, the magnetometer detects the flux using the electromagnetic or capacitive fields and generates an alarm in the form of beep sound or vibration.

3. The third approach is based on detecting the distance between a user’s smartwatch and earbuds using the strength of the Bluetooth Low Energy (BLE) signal. The received signal strength indicator (RSSI) is measured while the communication between the Bluetooth module in the smartwatch and earbud takes place. The RSSI value indicates the approximate distance between two BLE modules, and this principle is used to find the distance between the earbud (close to the face) and the smartwatch (hand). When the distance is below a threshold, an alert can be generated as the user is approaching the face with their hand. This model can
also be used to count the number of face touches or how many times the user is attempting to face touch.

All the above methods can be sensitive enough to detect a hand 20 cm from the face, which is far enough to deliver a timely warning in “alert” mode. The required mobile applications are developed, which are compatible with off-the-shelf hardware for this application. These devices do not stop anybody from touching their faces but only alerts the user through beep sound or vibration. If the user needs to touch the face and is sure about the hand’s cleanliness, they can ignore the alert and still touch their faces.

An Intelligent IoT Framework for Gesture Recognition to Achieve Contactless Interface and Social Distance [3, 4]

Control system design for controlling different devices through gesture recognition has been in practice for quite some time. Gesture recognition is an approach toward computing user interface that allows the system to capture and interpret human gestures as commands. One of the most intuitive methods for human-machine interaction is gesture spotting. These days, robots are performing predefined movements based on the gestures of human beings. These movements are generally executed in sequence to perform complex tasks. Gesture recognition can especially help persons with disabilities by having them wear sensors on their bodies.

Contactless interface is a key to control the spread of the COVID-19 infection among the people. Different devices required in our day-to-day activities like using lifts/escalators, opening door locks, controlling sanitizer dispensing systems, sending commands to a computing system, etc. can be achieved through gestures instead of touches. Avoiding touch, in any case, is the need of the hour.

A gesture is posture or movement of the user’s body, generally hand movements. Gestures can be used for interaction with others to convey messages and can convey messages through physical movements of the body, hand, face. Sometimes, facial expressions can also convey a message. Gestures also play an essential role in day-to-day life to interact with others. These gestures can also be used to communicate with a system known as gesture-based interaction.

Multimodal interfaces combining gesture, speech, and vision-based actions are expected to be available shortly for human-machine interaction. Natural ways of interaction with computers include speech-based communication wherein users directly communicate with the computer; gesture-based interaction where a human makes a specific predefined gesture to command a machine; and vision-based interaction where the computer does some predefined tasks concerning what it captures through the camera. These are natural ways of interaction that are more flexible and faster for interaction because speaking a word is more comfortable than typing through a keyboard. Speech-based interaction has the disadvantage that the same word may be pronounced differently by different people with different accents.
Speech recognition also suffers from external noise. Vision-based interaction has privacy problems, background effects, and limited coverage area.

Different types of sensors, along with various machine learning algorithms, have already been used for this type of application. Camera-based sensors and wearable-based sensors have been proved quite useful in this field. Although camera-based sensors provide higher accuracy, they suffer from high computational cost and are constrained by the field of view of cameras used in addition to privacy issues. Wearable sensors such as Inertial Measurement Unit (IMU), Electromyography (EMG) provide an energy-efficient and low computational cost in capturing gestures. EMG has been proved useful in health recovery monitoring, IMU in sign language recognition, and together they have been used to overcome limitations of each other. Despite their efficient performance, no popular and productive gesture-based control system has been developed and used.

In a gesture-driven interface, interaction with the controller happens using gestures of the human body, typically hand movements. One example of gesture-based interaction is that some mobile phones can take photos when we perform a predefined gesture. The gestures can be categorized as the following.

(a) Static gesture

In static gestures, users do not have to make any movement of the body while making a gesture. Static gestures are used in our daily life to show digits using only fingers. In this case, there is no physical body movement; the body’s position shows the predefined gesture. It is easier to classify static gestures compared to dynamic gestures.

The best application of static gestures is a sign language recognition system. In sign language, there is no physical movement of the body. The user simply shows characters of language by fingers as steady-state and position of fingers show particular gestures.

(b) Dynamic gesture

In dynamic gestures, the user makes body movement while making a gesture, e.g., waving hands to say goodbye. Here, action defines the gesture. Dynamic gestures are not more natural to classify because it includes lots of constraints like the direction of motion, speed of movement, and time elapsed for gesture presentation.

Both dynamic and static gestures are essential for system interaction and play a significant role in gesture-based systems for achieving touchless control. The touchless control can be achieved by using (1) ultrasonic sensor, (2) camera sensor, (3) accelerometer sensor, (4) gyro sensor among a few others. The complete system architecture is shown in Fig. 4.1.

In this gesture recognition system, the module records values from non-invasive body-mounted sensors, which are further transformed and processed by a model to extract features. This is accomplished by using methods of gesture segmentation and gesture recognition. The technique used for gesture segmentation is the adaptive
threshold algorithm, and for gesture recognition, deep learning methods like convolutional neural network (CNN) will be used. Sensor Gyro 6050 is used to generate a dataset of digits. For each digit, a dataset of 300 samples has been created. ESP8266 controller delivers a highly integrated WiFi system on chip (SoC) solution, which is used as a controller in this work. It has efficient power usage, compact design, and reliable performance in the Internet of things framework. An accuracy of 96.9 has been achieved using the mentioned algorithm for detecting gestures (identification of digits).

**Hardware and Connections Used**

The primary purpose of hardware is to read the sensors’ values corresponding to different gesture movements and send this as input to classification algorithms. The hardware consists of mainly two things, i.e., sensors, and controller. The sensor is responsible for reading values corresponding to different gestures. Sensors like IMU, EMG play a vital role in gesture-based technology. The controller receives values from the sensor and does the further processing. The different hardwares used in this system are the following:

a. **ESP controller**

The controller receives reading values from the sensor, and further processing can be done. Here, it uses the ESP8266 controller, as shown in the following Fig. 4.2.

The ESP8266 is a low-cost system on chip (SoC) microchip. It has a TCP/IP stack to send data over the internet using WiFi networks. It is capable of hosting an application on it and can execute functions from another application processor over the WiFi network. It is mostly used in the Internet of things (IoT).

Features of ESP8266:
- Low cost, compact
- Supports 802.11 b/n/g WiFi protocol
Fig. 4.2 The NodeMCU ESP8266 module [26]

Features: It can operate at input voltage within range 1.7–3.6 V. It comes with a Tensilica L106 32-bit RISC processor. This processor achieves low-power consumption and reaches a maximum clock speed of 160 MHz. It is also integrated with a real-time operating system (RTOS), which allows 80% of processing power to be available for user applications. ESP8266 module has the following features:

b. MPU6050 (Concept of IMU)

The system uses an IMU-based MPU6050 motion tracking device. MPU6050 is based on micro-electro-mechanical system (MEMS) technology. It can effectively collect information about gestures. It includes an accelerometer, gyroscope, and temperature sensor. The sensors have high sensitivity and can be fixed to wrist, arm, and other positions to obtain gesture data. It can be used to make new tools in gesture-based technology. This module is not affected by the external environment when collecting data and can be applied in a gesture-based interface. MPU6050

- Power supply: 3.3v
- Built-in low power 32-bit Tensilica RISC processor
- Current consumption: 100 mA
- 512kB flash memory
- support deep sleep (40 µA)
can measure the force of body, angular rates, and sometimes the orientation of the body using a combination of three-axis accelerometers, three-axis gyroscopes, and at times magnetometers. The accelerometer is used for measuring linear acceleration and gyroscope for the rotational rate in 3D axes. One of the essential features of MPU6050 is that it has an in-built Digital Motion Processor (DMP), which is powerful enough to perform the computation required for sensor data fusion. It uses the I2C communication protocol for communication with peripheral devices. It needs an input power supply of 3–5 V. It is a low cost, low computational cost, not sensitive to the environment, and energy-constrained sensors. A total of six features are captured using a three-axis accelerometer (Accelx, Accely, Accelz) and three-axis gyroscope (Gyrox, Gyroy, Gyroz) sensors. Figure 4.3 shows the pin diagram of the unit.

Features of IMU6050:
- Micro-electro-mechanical system [MEMS] technology.
- Three-axis accelerometer and three-axis gyroscope.
- 16-bit ADC to get digitized output.
- Power supply 3–5 V
- Communication protocol I2C
- DMP: Digital Motion Processor, which is powerful enough to perform the computation of sensor fusion.
Implementation

(a) System architecture:

The main goal is to design gesture-based interfaces to interact with computers. The system records values from non-invasive body-mounted sensors, which are further transformed and processed by a model to extract features. This is accomplished by using methods of gesture segmentation and gesture recognition. Gesture segmentation is the process of segmenting continuous data from sensor values to obtain actual data that contains a gesture using the threshold algorithm, and gesture recognition is the process of classifying this gesture into a predefined gesture. The following Fig. 4.4 shows the architecture of the system. Here, the controller continuously reads values from non-invasive body-mounted sensors. When sensor values reach the preset threshold value, system segments data are further transferred to classification algorithms. The classification algorithm classifies gestures into predefined clusters, and the system takes action according to the command given by gesture. The pictorial representation of the detailed process flow is given in Fig. 4.5.

Fig. 4.4 Node MCU8266 and MPU6050 connection diagram
Fig. 4.5 System flowchart of the gesture recognition system

The Interface Between MPU6050 and ESP8266

**Softwares used:**
- Arduino: IDE used to program ESP controllers.
- ESP Flasher: Used to flash the code from ESP.
- mPyloader: Used to transfer file and communication tool for ESP.
- Anaconda: used as programming IDE for CNN implementation.

This research and design aim to achieve social distance, which is very important to restrict the spread of any virus, particularly the “Corona-Novid-19” virus, which is communicable and spreads through touch-sensitive human-to-human transmission. This idea presents techniques to achieve the following without any touch (which is a pivotal component to restrict the spread).
1. Opening of door lock through gesture (by communicating a secret series of digits (PIN or password) which will be communicated to a server and the server verifies the PIN and if authorized, opens the lock and door (achieves contactless home entry)

2. Controlling the lift without touching the buttons of the lift
   a. Without touching the lift button, a person can ask for the lift through gesture.
   b. Once inside the lift, a user can use the lift by communicating a digit using gestures.

3. Controlling the home appliances switches through gestures.

4. Virtual reality (VR):
   Virtual reality is also known as a virtual environment. Virtual reality is a computer simulation that can create and simulate virtual worlds. Equipment, such as VR, headset, and data gloves, allow users to sense and control various virtual objects in real time. It creates experiences that users cannot obtain in the real world and generating an actual response.

5. Data gloves: Data gloves are one of the essential devices for virtual reality gesture-based interaction. Data gloves can collect data of posture and motion of real-time human hand movement indicating gestures. Gloves contain different sensors mounted on it. Generally, it contains inertial movement unit (IMU ) sensors. Data gloves can operate in two functions.

6. On the one hand, data gloves can act as an input device and collect the gesture movement of the user in real time and convert the received signal into virtual hand motion. Then, the user can observe the activity of the hand in virtual space through the movement of the virtual hand and can operate a virtual target by using various gestures. On the other hand, when using a feedback data glove in virtual space, the output of a feedback device enables the user to feel the target’s physical property during operation and increase realism.

Smart Glasses for Monitoring and Controlling the Infection Spread [5]

This section describes the design, development, and workflow of the smart glasses for COVID-19 detection and follow-up action. The smart glass is equipped with two different cameras: (i) the optical camera to capture detected face and (ii) thermal camera to capture body temperature and then process this information for detecting COVID-19 infection. A thermal camera is utilized for hot body detection and recognition by adopting the high-temperature variability compared to other objects within the scanned area. This module uses image segmentation techniques on the recorded thermal image (heat map). It then superimposes the thermal image segments with the colored optical image to detect the object’s face with high temperature. The face detection is processed using standard, and popular cascade classification algorithm [6], which is based on Haar features [7]. This system is completely developed using
the Android platform for compatibility with smartphones. The GPS module determines the location coordinates after tagging it and stores it along with detected face and temperature so that other health officers can access the data through a smartphone. The medical officer and health administrators will get the data about the person with high temperature and identify people with suspected infection of COVID-19 through smart glasses, as shown in Fig. 4.6.

The system will notify the person concerned and the health administrator sending alert messages together with captured face and body temperature data of the suspected

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**Fig. 4.6** System flowchart of the smart glass system
individuals. The system is implemented using Android Studio and Java programming language. The Android Studio will generate the android application that can be run on the smart glass device. The thermal camera software development kit (SDK) also needs to be configured inside the system to capture thermal images. The Viola-Jones fast face detection method [8] can also be used for detecting the face from the input optical images.

The prototype’s configuration is shown in Fig. 4.7, which describes the model with the thermal imaging, optical camera, Bluetooth communication, and Android framework for detection and identification of individuals with increased body temperature for the COVID-19 tracing and surveillance.

The Methodology

Thermography is the best method for scanning individuals and a large flow of people from a distant location in a contactless and non-intrusive manner. To do this, the temperature is measured, and an alarm triggered if it is above the standard threshold. This allows persons with increased body temperature to be identified quickly and reliably and isolated for more confirmatory testing. This smart glass-based system automatically detects high temperature via screening images, makes quicker diagnoses, and reduces human error risk, as shown in Fig. 4.7.

The screening process will be shown on the glasses screen that includes the detected face and the captured body temperature. The captured face and temperature are also stored in the database. The health officer and administrator can access the screening result after the data is shared from the smartphone. As soon as high body temperature is detected, the health officer will be notified through an alert.
message from the smart glasses. For example, when the thermal camera detects a high-temperature body, the system notifies the health officer to alert them regarding the risk. Besides, the system will take a picture using the optical camera and send it to the health officer.

All these are possible due to the rapid development in processing performance and memory, live video processing for computer vision in portable devices. The algorithms of conventional computer vision, image fusion, image segmentation, etc. have helped to develop the smart glasses system. Google location history (GLH) has been used to track user mobility, estimate the infection spread, control infectious diseases, and proper planning. The user’s travel and contact history are connected to the user’s Google account, like most Google features and services. The history of last visited places by the suspected carriers of the virus can be obtained through the Google location history (GLH) and can be used for contact tracing.

**Smart Wearable Thermometer for Continuous Temperature Monitoring:** [9, 10]

The researchers at IIT-Istituto Italiano di Tecnologia have developed a prototype sensor suit, namely “Smart Wearable Thermometer,” that can quickly screen human body parameters [9, 10]. Also, the smart band ready clients are triggered when their internal (body) temperature level is higher than normal temperature. While collecting the vital parameters of the human body, the smart band also emits radio signals, which another armband can receive. When two smart bands are coming closer, they estimate the distance between them using the received signal strength indicator (RSSI) value. If the estimated distance is too close (less than two meters), the band generates alerts in the form of vibration. In this manner, transmitting an alarm signal is used to help individuals maintain the most important “social distance” norms. The transmission of the radio signal uses an ISM frequency of 2.45 GHz, equivalent to Bluetooth communication [9, 10].

In many countries, individuals use armband and ring-like devices powered with AI strategy and cloud interface through “CloudMinds” [11] to give consistent checking of indicative symptoms like temperature, pulse, and blood oxygen levels. Hong Kong is also utilizing electronic tracker wristbands to alarm healthcare specialists and government authorities for people having international travel history and does not agree to home isolation [9, 10].
Connected Thermometers for Large-Scale Temperature Screening

Connected (network) thermometers [12] are being utilized by emergency clinics to screen patients and medical staff at different emergency clinics all through China and a few other countries. At present, they use a network of temperature sensors to screen COVID-19 patients to decrease the dangers of infection spread among medical staff. This device is designed and developed by a California-based wellbeing startup VivaLNK’s [12].

As shown in Fig. 4.8, this representative device uses a temperature sensor to monitor the temperature level continuously. This uses an IoT-based access controller to get ongoing patient information from the sensors and remotely transmit it to a healthcare station for continuous monitoring. This unit allows simultaneous data collection from a maximum of 40 Bluetooth Low Energy (BLE) devices to be combined and aggregated that is expected to cover numerous rooms in the clinic. Besides, from this, Kinsa Health [13] has utilized information collected from its more than one million associated thermometers to create day-by-day heat maps demonstrating which US areas are seeing an increase in detection and expansion of high fever.

Fig. 4.8 System to enable contactless control
**Small and User-Friendly Contactless Thermometer**

Temp Pal, [14], which is famous as the world’s smallest and most efficient thermometer, offers a cloud-based nonstop remote framework for temperature measurement and alerts clients/users whenever their body temperature is increased beyond an acceptable level. It is a small stamp-sized form factor with a weight of 3 grams and runs for 36 h for every battery recharge. It transmits temperature information through Bluetooth Low Energy to iWEECARE’s versatile application cloud [14]. It supports a one-to-many transmission protocol and helps with timely clinical treatment. The Temp Pal Cloud Cluster System helps control the spread of COVID-19 by monitoring the individuals in self-isolation [14].

**IoT Buttons for Generating Alert for Maintaining Cleanliness**

Visionstate structured its first Internet of things buttons [15], which was first used in medical clinics in Vancouver, Canada. The buttons are called Wanda QuickTouch that are used to send different types of requirements of the building premises, laboratories, nursing stations to a central controlling station. As shown in Fig. 4.9, the IoT buttons send instant alarms to the supervisors/administrators concerning any cleaning or upkeep activities to avoid the spread of infection.

The innovation empowers office supervisors to follow cautions and staff reaction times. The button interface to the central dashboard screen to remind the staff about the work to be carried out [15]. The IoT buttons are battery operated and equipped

![Smart IoT buttons](image)
with the LTE-M communication interface and are available in persistent rooms, nursing stations, bathrooms, or necessary zones. The buttons can be utilized related to cleaning and upkeep exercises all through an office building/ premises [15].

**Smart Helmet-Based Novel COVID-19 Detection and Diagnosis: [16]**

A helmet-like device based on IoT architecture has been proposed to detect COVID-19 infection and issue alerts. The smart helmet was equipped with two different types of cameras, allowing the gathering of detailed information of the face detection details and also temperature measurements. Optical camera and thermal infrared camera, which measures the temperature in a non-contact manner, try to find objects of interest. A thermographic camera or thermal imaging camera is a device that uses infrared radiation to create an image similar to that of a traditional camera that utilizes visible light to produce an image. This module of the smart helmet follows a segmentation approach for the image using the recorded temperature and captured color images by both thermal and optical cameras. Thermal cameras are utilized for hot body detection (based on the temperature) by observing the variability of high temperature compared with other objects within the scanned zone. If a thermal camera visualizes high temperature, then it creates high-intensity levels of infrared spectra. In this project, the Arduino IDE (Arduino integrated development environment) is used, which is written in Java language and represents a cross-platform application. This Arduino IDE contains many features like code editor, syntax highlighting, auto-indentation, and brace matching among a few others. The IDE additionally uploaded to an Arduino board by compiled and uploaded programs using an essential one-click mechanism. It also supports C and C++ languages in using special rules.

Further, it utilizes a wiring project that can produce several input-output methods to provide a software library known as wiring. Besides, Proteus software includes schematic, simulation, and circuit design. It is mainly used for drawing several schematics and performing real-time circuit simulation that empowers users to get access during the running phase, and thus creating a real-time simulation. For the face detection process, this prototype uses the EmguCV cross-platform [17], net wrapper, Intel OpenCV image processing library, C#, and.Net framework. The standard APIs are generated during programming by the OpenCV library. The face detection is done using the cascade classification algorithm proposed by Paul Viola and Michael [18]. This algorithm mainly uses the Harr feature for face detection. This feature is quite useful in this project as during COVID-19, people are advised to wear masks and cover most parts of the face. Further, a machine learning algorithm is used with a cascade function to train both positive and negative images. The OpenCV library already has the cascade object detection that recognizes the face of the captured
image. Many standard features are extracted from the human face to make a standardized size rectangle to enable standard image preprocessing algorithms to work on this. Figure 4.10 shows the smart helmet design model.

Through the smart helmet system, persons with increased body temperature can be identified quickly and reliably, and to be isolated for more exact testing and follow-up action. Beyond checking body temperature, artificial intelligence is being used to diagnose COV19. “Infervision” software platform that automatically detects symptoms via screening images and can make diagnoses quicker and reduce the risk of human error is also integrated with this system.

Figure 4.11 shows the detailed configuration of the system. The system concerns applicable thermal imaging frameworks for the detection and identification of an increase in body temperature as well as the surveillance process. This system uses an
enhanced helmet-fixable camera system that can be promptly deployed and utilized to visualize a thermal image with high resolution for the infected site.

The thermal imaging is coordinated to an optical camera for detecting the high temperature as well as the infected person in a contactless manner in a sensitive zone efficiently. Thermography is an ideal method for scanning individuals and large flows of people like at airports, railway stations, supermarkets, movie halls, and many such areas. For this, the temperature is measured, and alarm triggers in case it crosses the threshold value.

Face recognition has been exhaustively studied in the last few decades, and this device uses standard face recognition algorithms. Figure 4.12 illustrates the workflow of the proposed smart helmet.

![Workflow description of smart helmet system](image)

**Fig. 4.12** Workflow description of smart helmet system
IoT-Based Drone Technology for Mitigating Challenges Owing to Coronavirus [19]

In this proposed system, an unmanned aerial vehicle (UAV) is used to gather more information about the COVID-19 infected people whenever it is required. A significant module in UAV is the drone control module. This system module is interfaced with a GSM module and IoT technologies, as shown in Fig. 4.13. This system is designed to deliver an emergency call to the central station in case it detects the temperature of a person more than a threshold (suffering from fever). The emergency message includes the location tag (measured by the attached GPS module) information of the person detected with high temperature. The entire emergency call is handled by the smartphone app working with the GSM mobile network. The UAV design consists of three parts. The first part details the mechanism of the input source. The processor development is carried out in the second part where the microcontroller is integrated, utilizing the Arduino IDE for embedded coding. The third part of the system is focused on the mechanism of output source, which consists of the integration of mechanical segments.

The UAV is equipped with two different cameras, allowing the gathering of detailed information on the temperature and the face of the people. Optical camera and thermal camera provide information about the temperature at which the different faces of interest are spotted. This module relates to an approach of image segmentation according to recorded temperature and captured colored images obtained by the thermal and optical cameras, respectively. A thermal camera is utilized for hot body detection and recognition by adopting the high-temperature variability compared

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**Fig. 4.13** Workflow of drone-based surveillance system
to other things within the scanned area. If the thermal camera visualizes the high-temperature body, it generates high-intensity levels of the infrared spectra. Since the pilot controls the drone to the designated area, virtual reality is being used along with live video monitoring to control the camera to scan people.

After the drone arrives at a specific location, it will start to scan the people’s body temperature. The cameras that do the scanning will then transmit the live video monitoring clip to the smartphone. The live video monitoring is connected with an application on a smartphone so that the user can receive continuous live scanning from the entire flight by the drone. It will also create a realistic search operation during the flight but less interaction with people.

The drone control module is in charge of controlling both plans and actions of the drone. The drone is deployed from the central station after establishing the trajectory for its independent journey. The targeted destination point of the way was the GPS location gotten through the emergency call. The provided mechanism was tracked entirely and monitored within the control unit with the assistance of an online video stream. A GSM association and IP-based communication were coordinated to guarantee that there was a consistent connection between the central station and the field individual. The proposed system involves two cameras that track and monitor the assigned scanned zone. The drone is deployed to perform depicting visual and thermal cameras and collect more information for a precise hazard investigation. Optical and thermal sensors will be utilizing algorithms for detecting the hot body temperature by using an image processing module to distinguish and evaluate the dangers.

Drones and smartphones are integrated using WiFi signals, while camera control uses gyroscope data from an Android smartphone. The gyroscope is encompassed or embedded within the IMU. The drone IMU, along with GPS module, is used in the flight controller system. The camera that is fitted in the drone will scan the people; the live video will be transmitted through the headset connected with an IMU, which interfaces to the microcontroller. The working principle of the drone based is shown in Fig. 4.14.

After getting information involving the proper body temperature and GPS position from the Arduino through sequential communication, the microcontroller (NodeMCU) that had these observations transferred to it over the Web to allow autonomous online global access to this data. Moreover, the system collects and delivers situation reports based on a predefined schedule or on-demand. When the thermal camera detects a high-temperature body, the system notifies the authorities to warn them regarding the risk. In conjunction, the system will take a picture and sent it to the health administrator.
The tracing of COVID-19 positive patients is brought out generally through versatile applications, e.g., Aarogya Setu. As of April 21, 2020, Aarogya Setu takes a shot at the idea of publicly supporting. According to this current application’s client audits, the usefulness of cautions to close by clients is restricted, since it accepts that each individual that has a cell phone has this application introduced. The clients have likewise demonstrated worries about the authenticity of the information entered in the application, proposing a requirement for checking or supporting power. Although the versatile application based on the following appears to be lacking, a visual marker-based following technique (e.g., clinical specialists stepping on the hands with a non-launderable ink) is best in recognizing the slipping off COVID-19 isolate subjects. Along these lines, to identify the quarantine subjects on schedule, none of the two
referenced plans, as mentioned above, appears to work effectively and some way or another disregards the protection of subjects too. Different healthcare providers propose the utilization of wearable devices makes a patient increasingly consistent with clinical schedules and limitations; along these lines, a wearable band would be a correct answer for this case. Subsequently, a structured wearable band packaged with a versatile application would distinguish and follow the quarantine subjects continuously.

This wearable band is implied possibly to be taken off when a pre-decided isolate period is finished. Concerned clinical specialists have control of the following framework and answerable for the underlying subject enrollment, which lessens the security worries of the isolated subjects just as guarantees the authenticity of the information. GPS-based geofencing creates a framework for cautions and permits specialists to recognize isolated patients progressively. The versatile application additionally reports about any disembarkation or altering of the wearable band during a functioning isolate. Figure 4.15 displays the IoT-Q-Band framework’s design. As the wearable band is fueled up with a battery and ought to be lightweight for agreeable wear, have re-utilized a few cell phone highlights, e.g., Web, and GPS get to utilize the application.

The IoT-Q-Band framework integrates clinical facilities and also liable for setting the term of the isolate and confirming the quarantine protocols. The wearable band is worn by an isolated subject either on the hand, arm, or leg and remotely associated with the portable application using a Bluetooth interface. The handling unit is the ESP32. After detecting, the band transmits the status (a byte of information) to the portable application at like clockwork stretch. The subject will be enlisted.
An assigned individual can screen each enrolled isolate case using a Web interface that brings every compelling case and present in a decipherable structure. The progression of the information beginning from the wearable band until the observing Web interface (administrator dashboard board). Figure 4.16 depicts the system embedded in the cloth and to be worn by the patient at the wrist and leg [20].

**COVID-19 Intelligent Diagnosis and Treatment Assistant Program (NCapp) [21]**

It is an application based on the Internet of things. Eight different modules are implemented in real-time online communication with the “cloud.” All relevant and essential health parameters, together with travel history, possible contacts, are communicated to a designated cloud. According to these data, questionnaire responses, and check results, the diagnosis is automatically concluded as confirmed or suspected COVID-19 infection. It classifies patients into mild, moderate, or severe. The nCapp application also established an online COVID-19 real-time database, and it keeps updating the model of diagnosis in real time based on the latest real-world data to improve diagnostic accuracy.

Additionally, nCapp can act as a treatment support system. Physicians, experts, and managers are also linked to the nCapp platform for consultation. The nCapp system [21] also contributes to the long-term follow-up of patients who suffered from COVID-19 infection. The ultimate goal of the intelligent nCapp system is to enable different levels of COVID-19 diagnosis and treatment among different doctors from various hospitals that can be upgraded to the national and international standards. In this way, it can block disease transmission, avoid physician infection, and control the epidemic as soon as possible.
Robots and Drones in Service of the Society During COVID-19

Robots are being utilized to ease the weight on social distance and aid the treatment of patients. The best case of this is from the recently referenced field medical clinic in Wuhan, a joint endeavor between CloudMinds, China Mobile, and the Wuhan Wuchang Hospital [22]. At the Smart Field Hospital—5G-enabled robots to supply food, beverages, and drugs to patients. Notwithstanding, providing an essential break to staff and the robots’ utilization restricted the social distance between infected patients. Robots from organizations like UVD Robots and Xenex Disinfection Services are being utilized to disinfect emergency clinics and others in affected areas in China, Italy, and the USA.

As discussed earlier, drones are being used to send clinical examples and supplies to and from COVID-19 hotspots [22]. The Japanese organization Terra Drone utilized drones to move supplies in China. Government authorities all through China, France, Spain, and the USA use drones to screen and guarantee delivery of essentials during the lockdown. Robots and drones are being utilized to splash sterilizing chemicals in some open spaces and on vehicles going between affected zones.

Systems That Indirectly Ensures Social Distancing

Different IoT-based systems are in use to ensure social distancing using Bluetooth communication, GPS-enabled systems, smartwatches, and other things. There are a few other systems that also indirectly helps in ensuring social distancing. Some of the following practices based on the sensors and IoT framework and other modes that indirectly help social distancing are as follows.

- Using existing CCTV and IP cameras to continually monitoring the movement of people and using video processing techniques to find the distance between them can ensure social distancing in many areas. The system can generate alerts whenever the computed distance between persons is less than the prescribed minimum distance of two meters.
- Contactless (touchless) participation framework: Many interesting innovations are now put to practice to promote touchless operations in day-to-day activities like gesture-based command control, foot operated doors, among few others.
- Telemedicine answer for healthcare institutions: Online and remote healthcare, which were there for quite some time, suddenly hog the limelight. People who were hesitant and questioning the efficacy of remote healthcare are now exploring this as a suitable alternative for the treatment of normal ailments. Some of the standard practices being followed are the following.
  - Specialist schedule planning
  - Conference utilizing video calling
Systems That Indirectly Ensures Social Distancing

– Remedy dealing with the patient.

**Monitoring Food Safety During the COVID-19 Pandemic [23]**

The Internet of things (IoT) is changing the way restaurants and customers are engaged in the food business in the pre-COVID era. Today, both the restaurant owners and customers can trace products from the source to their doorstep of customers using IoT devices. The IoT device can monitor the delivery boy’s location and the food’s temperature while on the way. These devices have become very popular and quite helpful in keeping the food safe while in transit. This also helps in the proper management of inventory and giving owners real-time information to efficiently manage multiple locations.

Society is now more concerned about possible future outbreaks, and it can be a foodborne illness outbreak. The food industry should be more vigilant and alert to arrest any such outbreaks. Unfortunately, if it happens, we need to know which products are involved and the source location of the outbreak. IoT devices can be of great help in these scenarios as they allow owners to track their food from the time the order to the time it arrives. Even when the food items are on the highway, owners can still monitor the temperature and other physical and chemical parameters of the food, to ensure that safety standards are strictly followed.

Food-based businesses are now mandated to establish preventative control systems modeled after Hazard Analysis and Critical Control Points (HACCP) guidelines and prove their compliance by maintaining at least two years of data and documentation. IoT framework can help the business owners gather the data, store it for future auditing and, most importantly, ensure that the customers get the quality food.

Thus, utilizing the IoT for food safety is a critical aspect of quality control. These devices are equipped with a controller, temperature sensor, other required quality sensors like pH, dissolved oxygen, etc., barcode scanner, GPS module, and RFID-based infrared temperature reader to monitor and track the food throughout its journey in the supply chain.

- The temperature sensor, infrared camera, and RFID scanner track and measure each product’s temperature during the supply chain.
- The IoT and cloud interface helps employees to complete checklists, including periodic temperature checks.
- The data collected in real time is immediately uploaded to a secure cloud that can be accessed anytime, from any location.
- Data analytics and user-friendly visualization can be done while the data is in the cloud. We can even customize, store, filter, and analyze the information according to our requirements.
- A detailed protocol for handling the food items can be prepared, and the sensors and IoT framework can be leveraged to ensure that. Alerts can be generated immediately if any steps of the protocol are overlooked, like non-observed items, missed
checklists, and corrective actions that address temperature or other parameter concerns.

- A detailed automated audit trail is generated and maintained to prove that it followed proper food safety protocol.

**IoT Devices and Modern Dining Experiences [24]**

In addition to the process of streamlining and managing day-to-day operations of the food business, IoT devices can also create a unique and pleasant dining experience for the customers. For example, if you love seafood, the restaurant can use IoT devices to provide a complete track history (where and when seafood is harvested) to customers. The “Boat-to-Plate” project funded by the Mid-Coast Fishermen’s Association, developed a mobile app for the fisherman to upload information regarding their catch. A mobile app with IoT framework and sensors integrated is developed to find the quality and nutrient content of the food on the plate. The customers are more than happy to know the quality and the nutrient component of the food that is being served as they can avoid certain ingredients that are not good for their health. Restaurant owners these days are using IoT devices and related information to create many such unique dining experiences.

**Inventory Control and Management [25]**

IoT devices can efficiently manage and reduce the cost of inventory by providing real-time data that helps to optimally decide the time of ordering stock and forecasting requirements based on their demand. Tracking inventory from farm-to-fork has many advantages like preventing food waste, detecting in-house theft, and reducing the cost of managing the cost of inventory. Other questions and action items that IoT devices can help manage the inventory efficiently include:

- Who placed the order, who authorized the purchase, and when accepted the delivery?
- What is ordered, and what are the products’ proper temperature and other parameter ranges?
- When did the order take place, and when did it arrive? When is its expiration date?
- What is the origin of the product, and how did it travel to reach the destination?
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