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UAV-Based IoT System for Public Temperature Surveillance Using Thermal Imaging

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Abstract
Elevated body temperature is often an early indicator of potential COVID-19 infection, making its timely detection crucial for controlling the spread of the virus. Resent research underscores the versatility and advantages of unmanned aerial vehicles (UAVs) in various civilian applications. Building on these strengths, this study presents the design and implementation of a UAV-based temperature monitoring system for public areas to be used by the authorities. The design and development of this UAV based system, equipped with a thermal imaging sensor, autonomously patrols a defined area to continuously monitor individuals' body temperatures. When a person with temperature above the normal threshold is detected, the UAV captures an image of the individual and stores it locally, while simultaneously sending an alert to a central control unit to initiate appropriate action. The system's successful development demonstrates the practicality and effectiveness of the proposed solution for real-time public health surveillance.

Keywords: Microcontrollers; Sensors; Target Identification; COVID-19; Area Monitoring

1. Introduction

The term Coronavirus Disease 2019 (COVID-19) refers to a contagious viral infection primarily affecting the respiratory system, believed to have genetic links to bats and rodents. While its precise origin remains uncertain, the virus causes common symptoms such as fever, cough, and shortness of breath. First identified in Wuhan, China, in

December 2019, COVID-19 rapidly spread worldwide. Even in 2025, it continues to pose a significant challenge to global health systems, prompting governments to implement various control measures (Iqbal, Iqbal, & Bashir, 2022). To curb transmission, many authorities have adopted technological interventions aimed at identifying and monitoring infected individuals. For example, thermal imaging cameras have been deployed in public spaces such as warehouses and markets to screen body temperatures before allowing entry. Recently, Unmanned aerial vehicles (UAVs) have gained widespread use across multiple domains, including public health (Asmi & Bashir, 2025) (Bashir, Iqbal, & Yusof, 2022). Literature shows, UAVs applications in healthcare is growing, particularly for remote surveillance, communication, and access to restricted or quarantined areas (Kibab & Bashir, 2023). Since crowded environments can significantly contribute to virus transmission, as asymptomatic individuals can unknowingly infect others. Upon identifying a person with a high temperature, an alert is triggered. The surrounding area then can be isolated to help prevent further virus transmission, simplifying the process of identifying potentially infected individuals. Hence, technologies like UAVs can offer promising solutions for monitoring and mitigating the spread of infectious diseases.

In this background, this research work focuses on integrating a thermal sensor with an UAV for remote temperature monitoring in crowded areas, a key symptom associated with COVID-19 infection (Polonelli, Qin, Yeatman, Benini, & Boyle, 2020). The remotely controlled UAV, equipped with a camera (Bashir, Yusof, & Iqbal, 2022), is used to detect elevated body temperatures among individuals in public gatherings or roads (Bashir & Yusof, 2019). The UAV follows a predefined flight path across the target region while continuously monitoring ambient temperature. The microcontroller onboard compares the measured temperature with a reference threshold. If an individual's temperature exceeds the limit, a warning is displayed on the LCD panel, a red LED is activated, and the microcontroller captures an image of the individual via the onboard camera, and a notification is transmitted to a central control unit via WiFi. The rest of the paper is organized as follows: Section 2 presents the technical literature review, Section 3 details the project implementation methodology, Section 4 discusses simulation results and hardware implementation, and Section 5 concludes the study and provides recommendations.

2. Literature Review

The implementation of modern technologies, such as unmanned aerial vehicles (UAVs) equipped with cameras, infrared sensors, and wireless thermometers, has the potential to save lives, particularly in managing pandemics (Bashir, Yusof, & Iqbal, 2022).. Authorities and event organizers can utilize these UAVs to monitor the health status of drivers and attendees effectively (Alizadeh, Allen, & Mistree, 2020). Research shows that various projects have leveraged robots and their ability to socially interact with humans by tracking facial temperature to infer emotional states, given the physiological connections involved. This capability enables robots to develop a form of awareness by observing their effects on human conditions and responding appropriately (Saha, et al., 2018).

A humanoid robot named Meka is reported in literature that used a thermal imaging sensor to remotely detect temperature changes on individuals' faces during interaction (Robotics, 2012.). In this study, the robot's vision system was tested with 16 participants with varying distances, and heights across different settings. Significant changes in facial temperature were recorded during testing by detecting temperature shifts when the robot was close to the participant. These test results were promising, suggesting that temperature variations on the face could serve as indicators of emotional and physiological responses during social interactions study. Following this concept, the intention of this study is to design a thermal imaging-based system mounted on a UAV, which can monitor temperature changes induced by social pressure on the participants' faces. Particularly the nose in face area is significant where increase in temperature is more evident. Moreover, an interaction effect between the robot's proximity and its visual orientation that was found to influence this temperature variation. These insights highlight the potential of physiological detection robots to better understand human-robot engagement, preferences, and to foster more natural interactive behaviors.

(Gupta, Maurya, Mehra, & Kapil, 2021) research work proposed the use of thermal cameras as an innovative method for detecting individuals with fever by monitoring the temperature changes. In this work, when the system identifies a person exhibiting a high fever, it promptly alerts the management to enable appropriate interventions. Similarly, this study introduced a strategy that dynamically sets temperature thresholds based on real-time interactions with individuals aiming at accuracy of fever detection. The core objective of this research was to elucidate the relationship between temperature and pixel values captured by a thermal image sensor, as part of a thermal model project. Understanding these correlations enhances human detection capabilities and risk assessment processes. Unlike traditional cameras, which can be affected by lighting conditions and noise, thermal cameras provide more reliable data for simulation outcomes. The system achieves approximately 90% accuracy in human detection based on performance metrics and output quality. Thermal images are directly captured through the thermal camera, and the temperature at the center of each image is calculated and compared against the present reference values. The significance of this work lies in precisely defining the link between pixel intensity values and actual measured temperatures. Specific conditions and object models have been established to clarify this relationship, which is critical for accurate thermal image analysis. Since temperature measurements are provided by thermal cameras that can be highly accurate, data can be captured and processed directly on the device to obtain optimal results (Lee, Bui, & Lo, 2018). Indoor environments such as classrooms have long been ideal settings for the spread of bacterial and viral infections like the flu. This risk can be reduced during the early weeks of the academic semester, since the proposed system continuously monitors students' body temperatures using multiple infrared cameras in class room setting.

When a student's temperature exceeds 37°C or shows significant fluctuations, the system automatically sends an alert to the school nurse via email. Configured to calculate the average body temperature of students based on ambient room conditions, this technology enables real-time monitoring through thermal cameras installed in classrooms. Moreover, the system integrates with the air conditioning unit, adjusting the classroom temperature accordingly: cooling activates if the average body temperature reaches 38°C, thereby promoting a healthier and more comfortable learning environment by limiting the spread of infectious diseases (Alkhayat, Bagheri, Ayub, & Noor, 2015).

This study further presents a fundamental identification technique that uses optical flow estimation based on motion data to detect elevated temperatures in thermal image sequences of individuals with fever. This system combines a physical approach with a light flow algorithm that prioritizes tracking moving objects over classification. By merging visible and thermal images, the system generates enhanced thermal visualizations. The thermal imaging camera automatically identifies the hottest areas in the image, enabling precise body temperature measurement. The design method focuses on extracting the medial central region from continuous thermal images captured at different angles and distances during monitoring. Then these are combined with a temperature information filter and qualitative analysis techniques for detecting influenza or fever. All captured data is accurately logged and configured to display temperature values for each image sequence. This fever and influenza detection system, utilizing thermal imaging technology, holds significant potential to support health organizations by enabling early identification of febrile individuals before full clinical assessment. The following section discusses the design and analysis of the proposed work.

3. System Design and Analysis

The typical embedded system development process in this research work follows the well-established engineering system development model (Alawi & Bashir, 2023). Specifically, V-model is employed to structure the project, as it schedules planning and testing phases concurrently in a sequential manner since this model is particularly suitable for small to medium-sized projects with well-defined and fixed requirements. Also, this model is known for its clarity and ease of implementation. The V-model consists of several stages arranged in a "V" shape where the initial stage involves gathering the project requirements including analyzing real-world problems or technological challenges faced by society. The subsequent stage is system design, focusing on how the system will operate to meet these requirements. This research aligns well with the V-model methodology, which can be effectively applied to hardware components controlled by various applications tailored to specific needs. This approach supports the entire lifecycle of the system, including design, development, operation, and maintenance.

The following Figure 1 breaks down how the project works with a clear block diagram. At the heart of the system is the Node MCU microcontroller, which connects to the IoT and handles the alert messages. The setup takes input from two key sensors, the MLX90614 for checking body temperature and a camera that snaps photos if someone has a fever. On the output side, an LCD screen shows the temperature readings, while an LED lights up as a warning when high temperatures are detected.

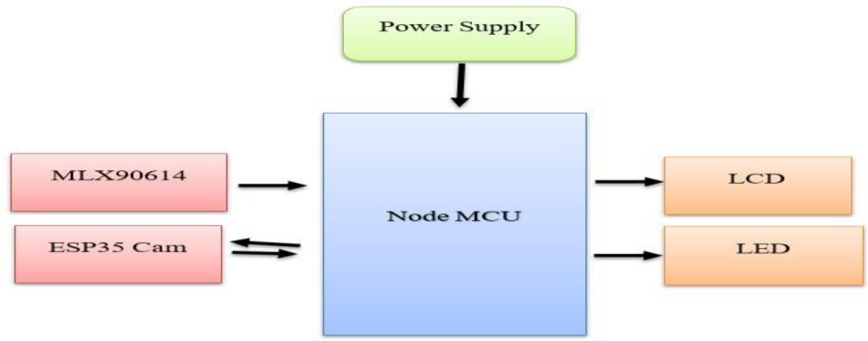

Figure 1: System Block Diagram

Figure 2 shows the step-by-step process of the system. The Node MCU acts as the brain of the operation, tying together all the inputs and outputs to process data accurately (Iotdesignpro, 2019). The system working can be devided into the following steps:

1. **Deployment & Scanning** – The UAV is flown wirelessly to the target area, where the MLX90614 sensor takes temperature readings.
2. **High-Temperature Detection** – If someone's temperature is above normal, the system immediately:
   - o Displays the reading on the LCD screen. o Lights up a red LED as a visual alert. o Takes a photo with the camera for records.
   - o Send a Wi-Fi notification to the control center.
3. **Continuous Monitoring** – After a 2-second pause, if the UAV is still active, it scans the area again for new readings.

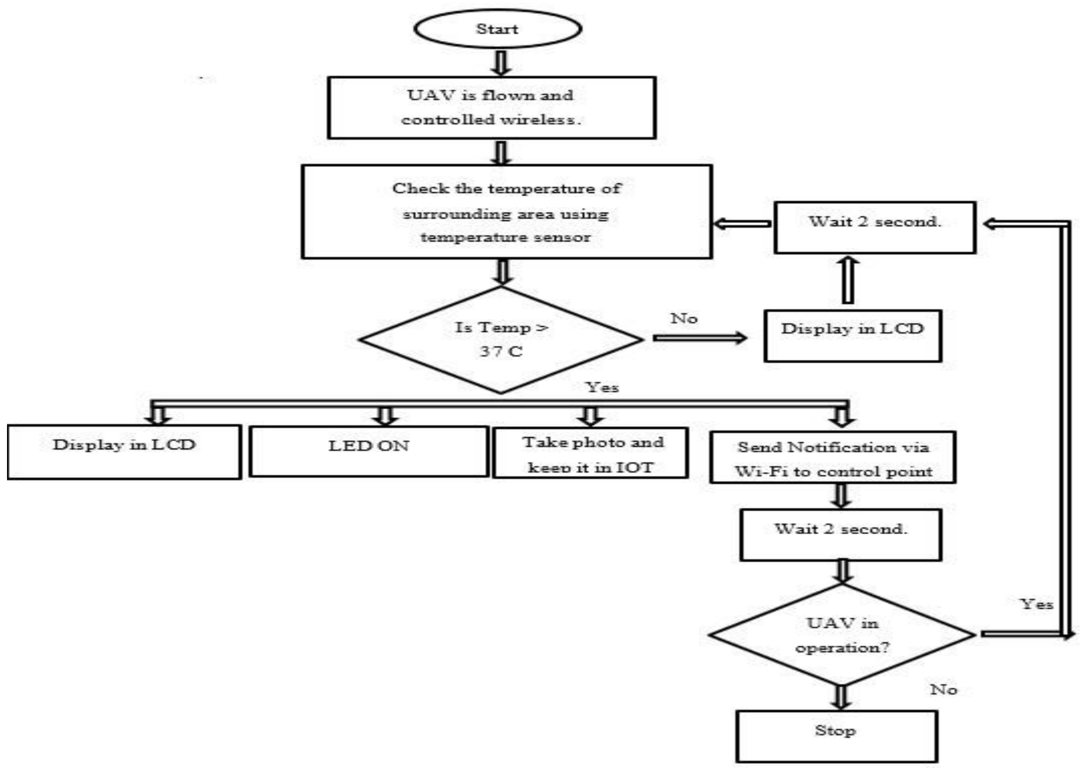

Figure 2: System Flow Chart

For this, the Node MCU (ESP-32 module) is programmed using the Arduino IDE. To get started, the Node MCU firmware is installed, and Wi-Fi credentials (SSID & password) are added to the code. The LCD display needs specific libraries—many come preloaded in Arduino's software and work with different LCD modules connected to the Node MCU. For configuring the MLX90614 sensor, header pins are first prepared and soldered onto the board to attach the sensor securely. The MLX90614 library must then be installed, and the sensor's internal thermistor readings can be monitored via the serial monitor at a baud rate of 9600. The sensor measures the average temperature within its infrared field of view, which is influenced by the distance between the sensor and the target object. Accuracy is affected by factors such as atmospheric conditions—including dust, humidity, and background interference—that tend to increase with greater distance and wider field of view. Notably, there is an inverse square relationship between temperature accuracy and the distance squared from the target object, meaning that accuracy diminishes as the square of the distance. This system detects human body temperature using a thermal camera so how to convert degree from Fahrenheit to Celsius using the expressions:

$$T(^{\circ}F) = T(^{\circ}C) \times 9/5 + 3 \quad (1)$$

Normal body temperature =37 °C degree

$$T(^{\{\circ\}F} = 37 \times \backslash frac\{9\}\{5\} + 32 = 98.6\sim\backslash text\{degree\} \quad (2)$$

To change the voltage to temperature this formula will going to be used:

$$\text{Temperature in Celsius} = \frac{(\text{output voltage in mV}) - 500}{10} \quad (3)$$

If output voltage=1V, the temperature will be (1000mv − 500)/10 = 50 degree Celsius
Nodemcu ADC is 10 bit and it inputs from 0 to 3.3V. So, the maximum value of ADC is:

ADC max value = 1024

The resolution of the ADC is the maximum voltage / maximum ADC value. ADC resolution = 3.3 / 1024 = 3.22mV, if the voltage that Nodemcu uses is 3V to turn the 10-bit analog reading into a temperature. To convert the number 0-1023 from ADC to 0-3000mV, following expression can be used:

$$\text{Voltage in pins} = (\text{reading in ADC}) \times \frac{5000}{1024} \quad (4)$$

4. System Implementation and Testing

To verify the sensor's functionality, it is essential to have an object ready for testing, measure its temperature beforehand, and then compare these values with the sensor's readings. Additionally, the camera must be programmed to capture images, with the ability to display the captured visuals, to ensure it is operating correctly.

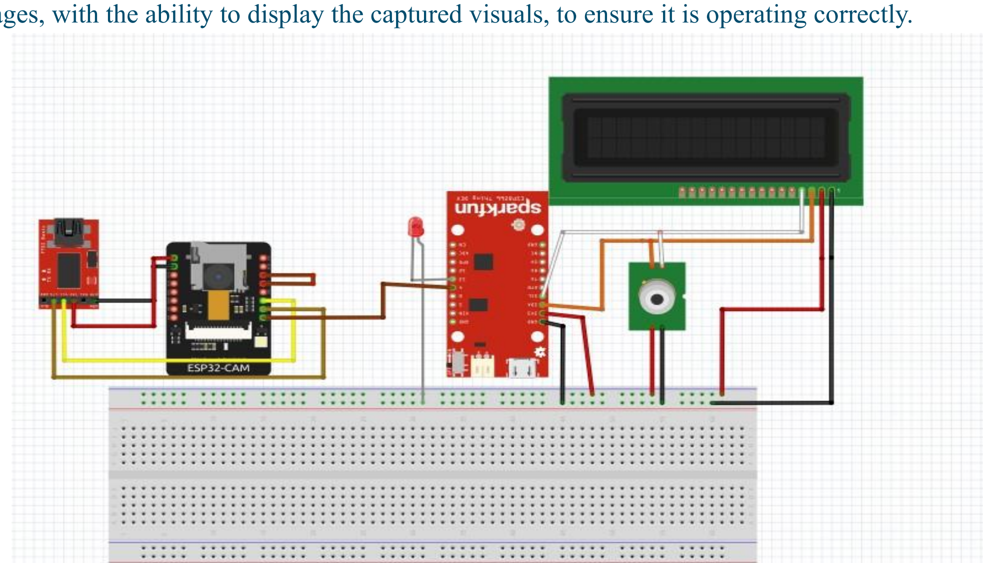

Figure 3: System Design

To test the functionality of the LCD panel, a command to display specific text should be provided, and the output must be evaluated. To verify the connection between the LCD screen and the thermal sensor, the screen should display the measured temperature. Additionally, the LED should activate only when a high temperature is detected, serving as an indicator to confirm the thermal sensor’s proper operation.

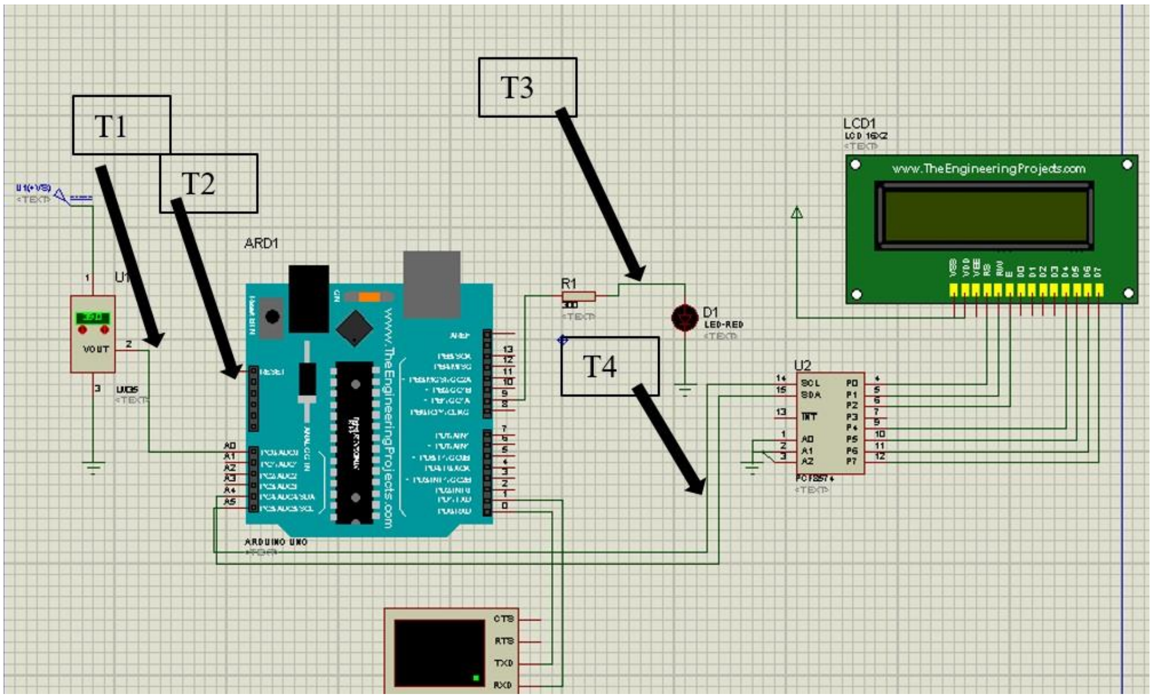

Figure 4: System Design in Simulation Software with Test Points

The Arduino UNO acts as the microcontroller and primary control unit of the circuit. The LM35 sensor serves as the first input device, detecting temperature and sending the data to the microcontroller. The LCD is the second major component, used by the microcontroller to display the temperature readings from the sensor. To reduce the number of input/output connections and minimize wiring, the LCD is interfaced using the PCF8574 module. The LED functions as the circuit’s output—the fourth component—and lights up when a high temperature is detected. Since the camera is not supported within the Proteus software, a virtual terminal serves as the fifth component, simulating the camera’s operation by indicating when the microcontroller triggers a notification and captures an image.

Table 1 presents the various test voltages based on the schematic illustrated in Figure 4. Minor differences exist between the simulation and implementation voltage values, attributed to variations in components used during implementation versus those in the simulation. Despite this, the implementation results closely match the expected voltage values. The system performed as designed: the person's image remained visible, and the red LED illuminated when a high temperature was detected. Given that the microcontroller has Wi-Fi capability, the Blink app was used to facilitate communication between the system and the control point. Connecting both to the same Wi-Fi network enabled easy receipt of notifications and captured images. The system’s experimental results are discussed next. To observe measurable effects, the temperature sensor was placed near a small candle. The red LED activated, and the LCD displayed the candle’s temperature accordingly. Table 2 summarizes the expected outcomes based on temperature thresholds, distinguishing between high temperatures ($T > 37°C$) and normal ranges ($T \leq 37°C$). Table 3 compares the results obtained from hardware testing and simulation, showing a close correlation between the two.

Table 1: Test Points for the Functional Units

Test point	Design voltage	Simulation voltage	Implementation voltage
T1	3V	0.32V	3V
T2	3-5V	3V	4V

T3	2V	2V	2V
T4	4V	3.8V	4V

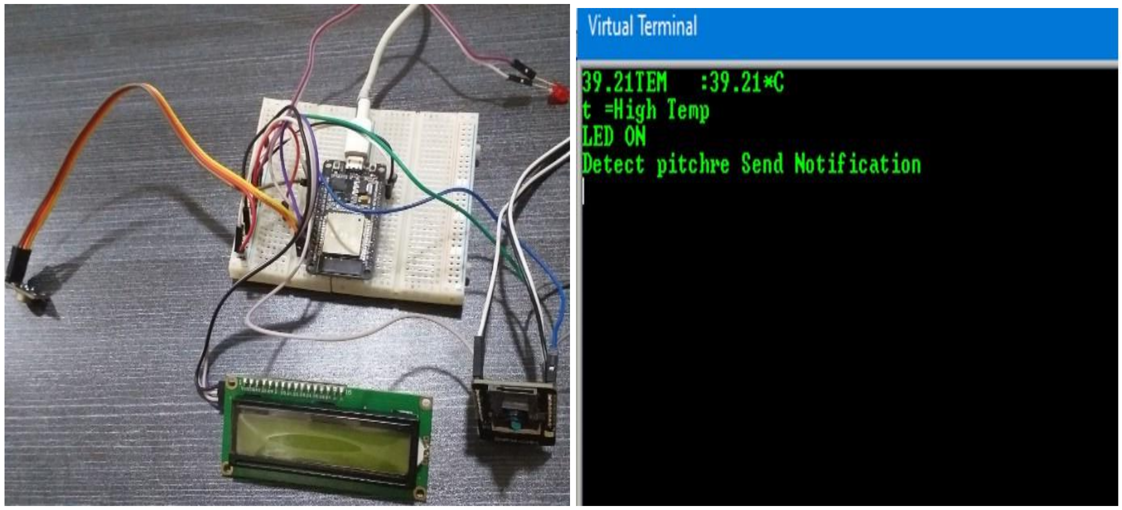

Figure 5: System Implementation and Virtual Terminal

Table 2: System Outputs

Sensor	Value	Output	Notification
Temperature sensor	T ≤ 37	Display in LCD the temperature detection, LED OFF, and the camera OFF	Green LED On
Temperature sensor	T > 37	Display in LCD the temperature detection, LED ON, and the camera will take a photo	Send notification to the control point “Warning! High Temperature

Table 3: Test Comparison Results

Test cases	Design			Simulation results			Implementation results		
	LED	LCD	Camera	LED	LCD	Camera	LED	LCD	Camera
T ≤ 37	OFF	Display temperature	OFF	OFF	Display temperature	OFF	OFF	Display temperature Print “Normal; Temperature”	OFF
T > 37	ON	Display temperature	ON	ON	Display temperature	ON	ON	Display temperature Print ”High Temperature”	ON Take a photo

5. Results Discussion

In conclusion, this technology—consisting of a temperature sensor mounted on a drone equipped with a camera to monitor the ambient temperature of a specific area—has the potential to assist in managing the Covid-19 pandemic. The device captures an image of individuals with the camera and sends an alert to the control center if their temperature exceeds the normal body temperature threshold. The V-Model methodology was selected for this project due to its simplicity and its emphasis on verification and validation, which help ensure accuracy throughout the process. Several related articles and projects with similar concepts or materials were reviewed, with detailed comparisons made to highlight the differences and adaptations in this project. The components used were described, and potential risks associated with the project were identified. After simulating the system, the results were analyzed and compared with the actual implementation outcomes. Overall, the project was thoroughly assessed, limitations were acknowledged, minor errors were found, and approximately 95% of the project objectives were achieved.

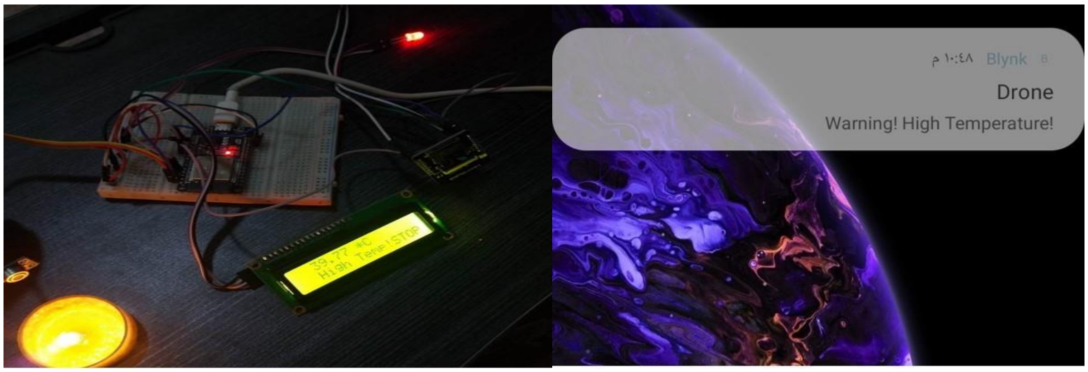

Figure 6: System Implementation Results and Notification on Blyc App

This report explains the idea behind the project and how it works. Since thermal cameras can measure temperature accurately across a wide area, we chose one over a standard heat sensor for this system. Getting precise readings is critical, so the sensor must be carefully calibrated to reduce errors. We also use signal processing to clean up the data, filtering out noise and keeping only the useful information. Of course, UAVs come with their own challenges—limited battery life, weight restrictions, and environmental factors like wind or weather. Managing these constraints is key to making this system work reliably and safely in real-world conditions. Looking ahead, this technology can adapt to detect symptoms of other illnesses beyond COVID-19, helping spot potential outbreaks faster and saving time and resources in future health crises. Using UAVs for temperature monitoring isn't just a technical challenge, it also raises important ethical questions. Privacy is a major concern, especially since the system takes photos. To protect people's identities, the data security measures, and clear consent policies should be in place. False alarms can be another issue. If the system mistakenly flags someone as having a fever, it could cause unnecessary panic or even lead to unfair treatment. That's why sensor accuracy and reliable detection algorithms are important. Public perception also matters a lot as not everyone is comfortable with UAVs surveillance. The attitudes may vary depending on the cultural and social factors and to build trust, transparency, compliance with regulations, and open conversations with communities is required. This will help people to see this technology as a tool for public health, not just another way to watch them.

Conclusion

This research demonstrates the successful implementation of a UAV-based thermal scanning system for COVID19 screening. By integrating a high-accuracy thermal camera and temperature sensor, the system effectively monitors individuals' temperatures across wide areas, automatically flagging elevated readings with image capture and realtime alerts to health authorities. The project adopted the V-model methodology, which provided a structured approach to development and validation, ultimately achieving 95% of its objectives with only minor operational limitations. The superior range and precision of thermal imaging proved significantly more effective than conventional heat sensors for this application.

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Conflict of interest: The authors declare no conflict of interest.

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