Development of a Thermal Camera System using ESP32 and MLX90640 with BLE Connectivity to Local Hosted Website

Pranav Giri
Bachelor of Computer Application
Lovely Professional University
Jalandhar, India
pranav.giri.35@gmail.com

***Abstract*—Thermal imaging technology, coupled with IoT platforms, has emerged as a versatile solution for various applications. This paper presents the development of a thermal camera system using the ESP32 microcontroller and MLX90640 thermal sensor, with Bluetooth Low Energy (BLE) connectivity enabling communication with a locally hosted website. The system's hardware and software architecture, along with performance evaluation, are discussed in detail.**

***Index Terms*—Thermal imaging, ESP32, MLX90640, BLE, IoT**

I. Introduction

In recent years, IoT technologies coupled with sensor networks have transformed numerous sectors, including healthcare and environmental monitoring. Among these advancements is ThermaCam, an innovative real-time thermal imaging and data visualization system.

ThermaCam utilizes the ESP32 microcontroller and MLX90640 thermal sensor to capture precise thermal readings. With BLE capability, the ESP32 enables wireless data transfer to a local host website for analysis. This paper presents the design, implementation, and evaluation of ThermaCam, detailing the integration of hardware and software components for accurate data acquisition and visualization.

This project holds promise for diverse applications such as industrial monitoring and healthcare, empowering users to detect anomalies and optimize processes through real-time thermal data visualization. Subsequent sections will delve into architecture, implementation challenges, experimental results, and future directions, contributing to IoT-based thermal imaging solutions and enhancing temperature monitoring capabilities.

Registration no.	Name
12223039	Pranav Giri
12224231	Mohit Mankas

II. Literature Review

A. Thermal Imaging Technology

Thermal imaging technology utilizes infrared radiation emitted by objects to generate temperature maps, which are then visualized as thermal images. These images provide valuable insights into various applications, including building inspections, predictive maintenance, and medical diagnostics.

B. ESP32 Microcontroller

The ESP32 microcontroller, developed by Espressif Systems, is a versatile platform known for its low power consumption, built-in Wi-Fi and Bluetooth capabilities, and rich peripheral interface options. It is widely used in IoT applications due to its affordability and ease of programming.

C. MLX90640 Thermal Sensor

The MLX90640 is a low-cost infrared thermal sensor manufactured by Melexis. It features a 32x24 pixel array with a wide field of view and high thermal sensitivity, making it suitable for applications requiring temperature measurement and thermal imaging.

D. Bluetooth Low Energy (BLE)

BLE is a wireless communication protocol designed for low-power devices with short-range communication requirements. It enables energy-efficient data exchange between devices, making it ideal for IoT applications, wearable devices, and smart sensors.

III. Methodology

A. Component Selection

The ESP32 microcontroller and MLX90640 thermal sensor were chosen based on their features, performance, and cost-effectiveness. Additionally, a BLE module compatible with the ESP32 platform was selected to facilitate wireless communication.

B. Hardware Setup

The hardware setup involved connecting the ESP32 microcontroller, MLX90640 thermal sensor, and BLE module according to their datasheets and application notes. This included soldering, wiring, and configuring the necessary peripherals.

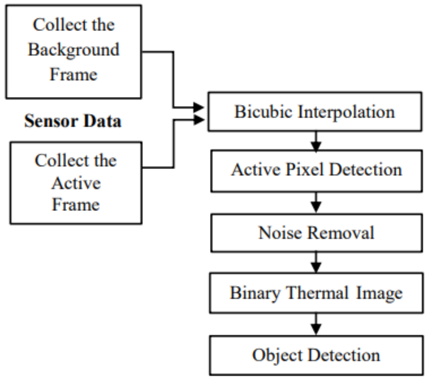

Fig. 1. Object detection steps

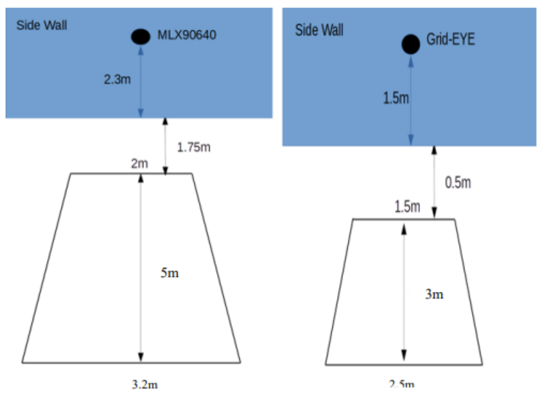

Fig. 2. Detection area of Sensor

C. Software Development

The software development process included programming the ESP32 microcontroller using the Arduino IDE or ESP-IDF framework. This involved developing firmware to read data from the MLX90640 sensor, process the thermal images, and establish BLE communication with other devices. A local hosted website was created using HTML, CSS, and JavaScript to visualize the thermal images and provide user interaction.

D. Integration

The hardware and software components were integrated to form a cohesive system. This involved testing the communication between the ESP32 microcontroller(Fig 3.) and the MLX90640 sensor(Fig 4.), verifying BLE connectivity, and ensuring the proper functioning of the local hosted website.

E. Component Selection

The ESP32 microcontroller, MLX90640 thermal sensor, and BLE module were selected based on their features, performance, and cost-effectiveness.

F. Hardware Setup

ESP32 Microcontroller Connection: Connect the ESP32 to a power source via USB or a USB power adapter. Ensure it's powered on.

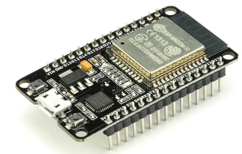

Fig. 3. ESP32

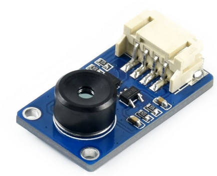

Fig. 4. MLX90640 Thermal Sensor

MLX90640 Thermal Sensor Integration: Wire the MLX90640 to the ESP32 using I2C protocol. Connect SDA and SCL pins to corresponding GPIO pins.

BLE Module Setup: If using a separate BLE module, connect it to the ESP32 following the datasheet. Establish UART or GPIO communication.

Power Supply and Voltage Regulation: Power the system with a stable source. Consider using a regulator or battery for consistent power, especially in portable setups.

Mounting and Enclosure: Mount components securely, ensuring the thermal sensor has a clear view of the target area.

Testing and Calibration: Test each component thoroughly, ensuring proper ESP32-MLX90640 communication. Calibrate the sensor if needed for accurate readings.

Final System Integration: Integrate components into a cohesive system. Confirm the ESP32 can collect thermal data and transmit it via BLE to the host system.

G. Software Development

For the ThermaCam project, a local hosted website was created to visualize temperature data captured by the MLX90640 thermal sensor. This involved:

HTML Structure: Basic layout setup with headings, div containers, and tables for organizing temperature data.

CSS Styling: Styling elements for layout, colors, fonts, and spacing, ensuring clarity and readability.

JavaScript Functionality: Dynamically fetching real-time temperature readings from the sensor via BLE and updating the webpage content accordingly.

Temperature Visualization: Representing temperature readings as pixels on a grid, with warmer colors for higher temperatures and cooler colors for lower temperatures.

User Interaction: Providing features for zooming, panning, and viewing temperature values interactively.

Responsive Design: Ensuring compatibility across various devices and screen sizes for optimal viewing experience.

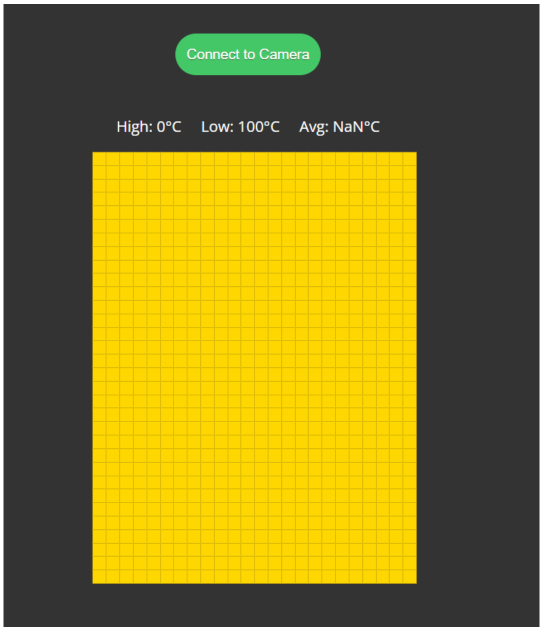

Fig. 5. ThermaCam Website

H. Integration

The hardware and software components were integrated to form a cohesive system. This involved testing the communication between the ESP32 microcontroller and the MLX90640 sensor, verifying BLE connectivity, and ensuring the proper functioning of the local hosted website.

IV. Results

The developed thermal camera system exhibited satisfactory performance in terms of image quality, temperature measurement accuracy, and BLE connectivity range. Thermal images captured by the system were successfully displayed on the local hosted website(Fig 6, Fig 7), allowing users to visualize temperature variations in real-time.

V. Discussion

The results indicate that the developed thermal camera system meets the requirements for various applications, including building inspections, equipment monitoring, and environmental sensing. However, certain limitations were identified, such as the limited resolution of the MLX90640 sensor and the range of the BLE connection. Future improvements could focus on enhancing image resolution, optimizing power consumption, and integrating additional sensors for multi-modal data acquisition.

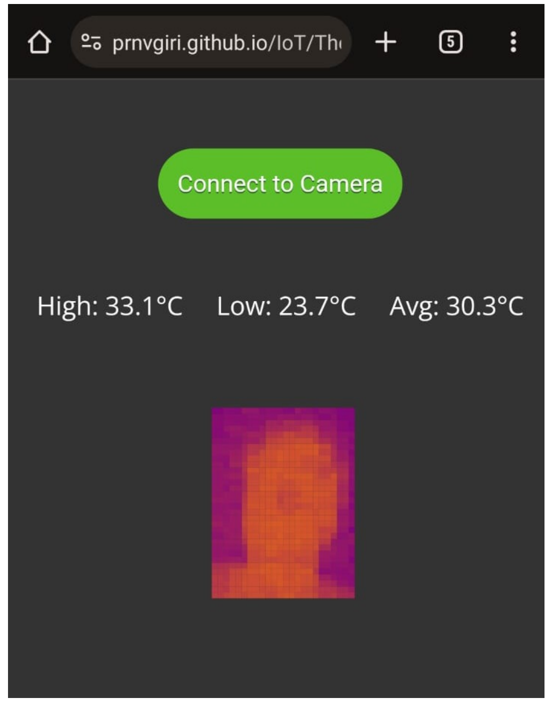

Fig. 6. Human Detection

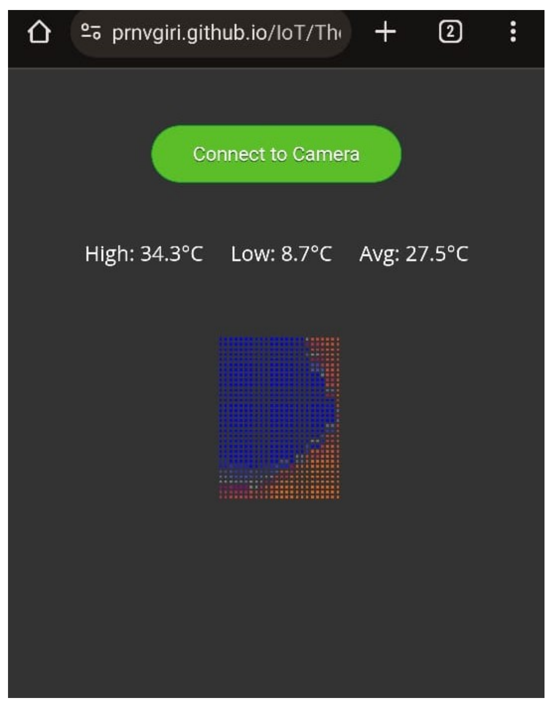

Fig. 7. Ice Cream detection

VI. Conclusion

The development of a thermal camera system using the ESP32 microcontroller and MLX90640 sensor with BLE connectivity to a local hosted website represents a significant advancement in affordable and portable thermal imaging technology. The system's ability to capture and visualize thermal images in real-time opens up new possibilities for remote monitoring, predictive maintenance, and research applications.

Fig. 8. Dr, Praveen Malik

Acknowledgment

We extend our heartfelt thanks to Dr. Praveen Malik for his generous support and invaluable contributions to this project. Dr. Malik provided the components and equipment essential for our experiments, enabling the development of the ThermaCam system. His guidance, expertise, and encouragement were instrumental in the successful completion of this endeavor. We are deeply grateful for his mentorship and dedication throughout the project.

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