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MICROCONTROLLER-BASED TEMPERATURE AND FACE DETECTION SYSTEM FOR UNIVERSITY LABORATORY CONTROL AND MONITORING

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Abstract

Efficient and reliable university laboratory management requires precise monitoring and control of environmental conditions such as temperature, occupancy, and equipment use. However, traditional monitoring methods such as manual measurements can be time-consuming, labor-intensive, and prone to error. Additionally, there is often a need for remote monitoring and control, especially in large facilities or during off-hours. To address these challenges, this paper presents the design and implementation of a comprehensive monitoring and control system for a university laboratory. The system employs an Espressif 32 (ESP32) microcontroller board and various sensors to automate temperature, occupancy, and equipment monitoring. Temperature readings of people entering and leaving the university laboratory are taken to ensure safety during a pandemic. Face detection is used to monitor the number of people entering and exiting the laboratory and to authenticate individuals entering. An ESP32 microcontroller performs commands using a relay switch after password-based authentication through SMS. Furthermore, the system can be remotely controlled via SMS through a GSM network, providing an effective way to manage university laboratory conditions from a distance. The system's accuracy was evaluated by comparing temperature readings with those of a reference thermometer and testing face detection and relay control functions. The results of the tests demonstrate that the system is reliable and accurate in monitoring and controlling the university laboratory environment. Overall, this system provides an efficient and effective solution for university laboratory management, reducing the need for manual monitoring and improving the accuracy of environmental data collection.

***Keywords**: Temperature monitoring, Smart Lab Control, Sensors, ESP32*

INTRODUCTION

The recent COVID-19 pandemic has drastically changed the way academic institutions operate worldwide . Since students often gather in classrooms and laboratories for practical classes, it has become essential to implement crowd control measures to maintain a safe environment for everyone. Crowd control refers to the measures taken to manage and regulate the movement and behavior of large groups of people in public spaces .

One of the most crucial measures is to limit the number of students allowed in a university laboratory at any given time, which can help reduce the risk of transmission by ensuring that physical distancing measures are followed.

Additionally, another measure that has been widely implemented is the use of temperature screening to ensure that no one with a fever or elevated body temperature enters the laboratory. This is done by measuring the body temperature of each individual and comparing it to a set threshold. Effective implementation of these crowd control measures is vital in ensuring that the virus is not spread among learners, as well as instructors and other staff members who are present in the university laboratory. By implementing these measures, academic institutions can help prevent the spread of the virus and ensure that students can continue to learn in a safe and healthy environment .

However, there are several problems associated with the existing methods of implementing crowd control measures in university laboratories. Firstly, limiting the number of students allowed in the laboratory at any given time can be challenging to enforce. Some students may not adhere to the rules and may try to sneak into the laboratory, which increases the risk of crowding and makes it difficult to maintain social distancing .

Secondly, monitoring the body temperature of students can be time-consuming and may require additional personnel. It is also possible for individuals with the virus to be asymptomatic and not exhibit a fever, making this measure less effective in identifying potential carriers of the virus. Lastly, some institutions may not have the necessary resources and equipment to implement these measures effectively. This can lead to a lack of consistency in the implementation of these measures across different laboratories and departments, which can increase the risk of virus spread .

Apart from the aforementioned, the use of traditional thermometers can also slow down the process of monitoring large crowds, leading to long lines and increased risk of exposure to the virus. These challenges have underscored the need for innovative methods of temperature measurement that are contactless, efficient, accurate, and capable of handling high volumes of people.

Specifically, there is an increased need for innovative methods of temperature measurement and crowd control measures in various settings, including educational institutions where students gather for lectures and laboratory practicals . This need for smarter laboratories was highlighted by where authors proposed a system that monitors temperature, humidity, and light intensity and uses a database to view status history. The results show that appliances in the lab can be remotely monitored and controlled, reducing their energy consumption.

developed a smart laboratory system on a campus using IoT and mobile application technologies. The system monitors the energy consumption, device utilization, and environmental parameters in the lab for improved energy efficiency and comfort. Similarly, presented the concept of a smart integrated laboratory, where IoT devices and technologies are used to control and monitor laboratory equipment. The authors describe a prototype system, Talk2Lab, that was implemented in a laser facility, and combines sensors, Raspberry Pis, camera feeds, and multiple interaction methods to facilitate laboratory communication.

Table 1: Description of Hardware Components

Hardware Component	Hardware Description
Microcontroller (ESP32)	A low -cost microcontroller with integrated Wi-Fi and dual mode Bluetooth. It acts as the center of the GSM module and enables wireless connectivity.
GSM Module (SIM800L)	A wireless modem that operates on a GSM network, with no limitations on distance. It works anywhere in the world and is controlled by sending commands to the microcontroller (Akhter et al., 2019).
Relays	Used to switch loads by receiving commands from the phone and being controlled by the microcontroller. Transistors are used in place of relays when multiple relays are required to switch at low currents.
IN4007 Diode	A rectifier diode that converts Alternating Current to Direct Current.
Infrared Proximity Sensor	Detects nearby objects without physical contact by emitting an electromagnetic field or infrared beam. The sensor allows the thermometer to take readings at a distance.
ESP32 Camera Module	A low -power, small sized camera module based on ESP32, used for IoT applications such as wireless video monitoring and Wi-Fi image upload.
AC -DC Converter	Converts incoming and outgoing voltage for the Smart Lab board, protecting the board and producing proper voltage for lab equipment and lighting.

SYSTEM ANALYSIS AND DESIGN

We analyze the system into four key sections: power, input, processing, and output. The design procedure for these sections is described next;

Power Section

Two components make up the power source: a primary source and a secondary source. The primary source is a Lithium-Ion battery, with a voltage range of 3.7V to 4.2V. The secondary source is a step-down transformer that converts 220V AC to 5V DC, which charges the battery. Additionally, a boost converter is utilized to maintain a stable 5V voltage by converting the low voltage from the battery. The system's circuit diagram is shown in Figures 1 and 2.

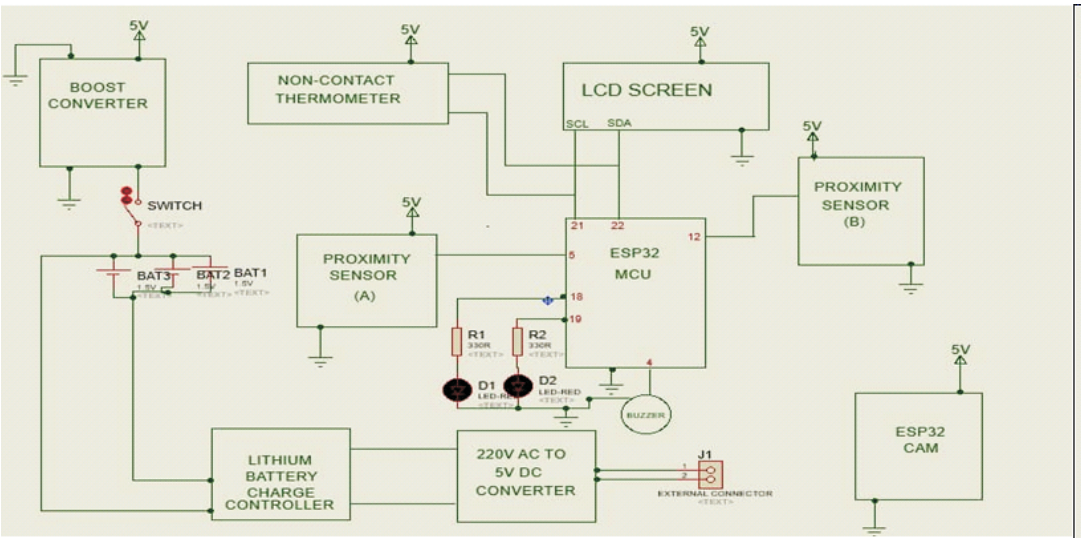

Figure 1: Circuit diagram of the proposed System

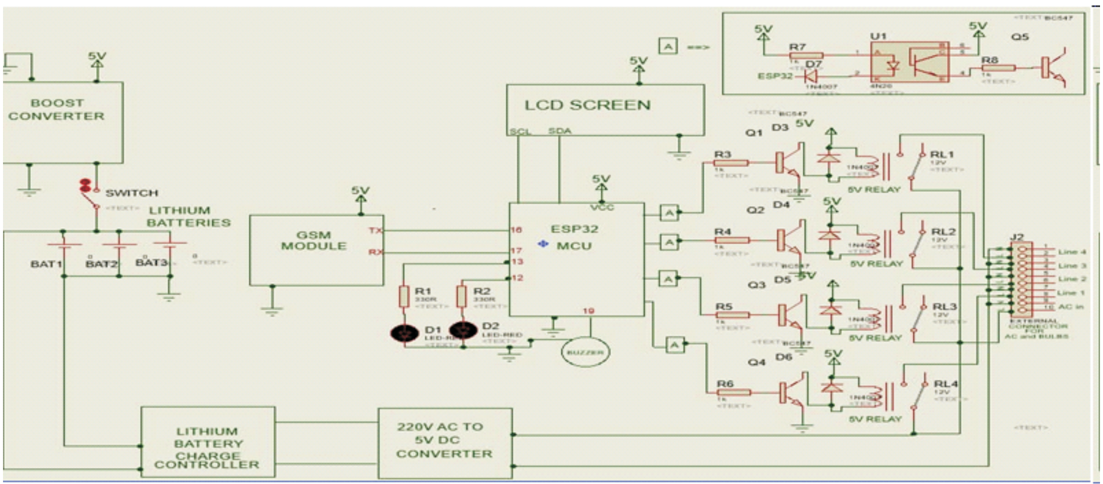

Figure 2: Circuit Diagram of the various modules of the Micro-Controller unit

Input Section:

The input section of the system comprises a GSM module and a thermometer. The GSM module receives commands from the user, while the thermometer measures the temperature of an object and triggers an alarm if the temperature surpasses the set value.

Processing Section

The ESP32 microcontroller is responsible for processing commands received from the GSM module, camera module, and thermometer. With its 3.3V pin and 36 I/O pins, the ESP32 is well-suited for the system design and is powered directly by the boost converter . The Arduino functions as the core of the project and handles the interpretation of the received command, triggering the buzzer or relay as needed. However, the output pins of the Arduino are insufficient to power the relay coils. To address this, a resistor-transistor arrangement is used to amplify the current and enable the relays to be powered from the primary 5V DC supply without overloading the Arduino pins.

Output Section

The output section of the system comprises several components, including a relay control unit, buzzer, LCD, and RGB LEDs. The relay control unit is responsible for switching various appliances connected to the system's output, with a maximum contact rating of 10A and a maximum voltage of 270VAC/28VDC. The buzzer produces an alarm sound when the thermometer senses a value above the set threshold. The LCD provides information on the state of the device and the output from the thermometer, while the normal and RGB LEDs indicate the device's power status and output. Tables 1-2 present the specifications of some hardware components used in the system.

Table 2: Specifications of the thermometer device

Feature	Value
Supply Current	1.5mA
Operating voltage	3.6V– 5V
Object Temperature Range	-70 – 382.2 degree
Ambient Temperature Range	-40 – 125 degree
Accuracy	0.02 degree
Field of view	80 degree
Distance between object and sensor	2cm– 5cm (approx.)

Table 3: ESP32 Technical Specifications

Feature	Value
Operating Voltage	3.3V
Voltage for Vin pin	7V – 12V
Analog Input Pins	Up to 18
Digital I/O Pins	36
DC Current on I/O Pins	20 mA
DC Current on 3.3V Pin	40 mA
Flash Memory	4 MB
SRAM	520 KB
WIFI	802.11 b/g/n
Frequency (Clock Speed)	160 MHz to 240 MHz
Communication	SPI, I2C, CAN, UART, I2S
Bluetooth	V4.2 BR/EDR and BLE
Touch sensors	10

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Load Analysis

The load analysis involves calculating the current requirements of various appliances, including bulbs, air conditioners, fans, and televisions, and determining if a 5V, 10A single pole double throw relay on a single-phase supply can handle the load. For example, a 25W bulb requires 0.11A of current, allowing the relay to handle up to 90 of these bulbs. However, an air conditioner (AC) with a 2.5KW power rating requires 11.3A of current, exceeding the relay's 10A rating, and thus cannot be controlled using the relay. For a 300W appliance such as a fan or television, which requires 1.36A of current, the relay can handle up to 7 of these appliances.

PSEUDOCODE

The pseudocode explains the software design of the system.

Step 1: Import necessary libraries
Step 2: Create objects for the MLX thermometer, ESP32 Microcontroller, and LCD
Step 3: Declare variables for RGB LEDs, relays, relay LEDs, sensor pin, and buzzer
Step 4: Set the states of the flashers
Step 5: Initialize the libraries and set pins as input/outputs
Step 6: Display a welcome message
Step 7: Set temperature range between 36.3℃ and 37.3℃ and counter to 30
Step 8: Test the design
Step 9: If the temperature is above range, activate the buzzer and turn on the red LED
Step 10: If the temperature is within range, turn on a green LED
Step 11: If a face is detected, turn on the blue LED and activate the relay
Step 12: Display temperature and face detection status on LCD
Step 13: Repeat steps 9-12 until the counter reaches 0
Step 14: Display the end message on LCD and turn off the LEDs and buzzer
Step 15: End the program

RESULTS

Implementation

After ensuring that all the connections are properly made, the system is powered on by connecting it to the main power source. The boost converter and step-down transformer work together to provide a stable 5V DC supply to the system. The system is then initialized by loading the required software and setting up the necessary parameters, such as the temperature threshold for the thermometer and the number of people threshold for the camera module. Once the system is initialized, it starts monitoring the temperature and the number of people in the university laboratory. If the temperature exceeds the set threshold or the number of people exceeds the set limit, the system sends an alert to the user via SMS and triggers the alarm buzzer. The LCD shows the status of the appliances, the temperature, and the number of people in the university laboratory.

The user can also control the appliances by sending SMS commands to the system through the GSM module. For example, sending the command "AC ON" will turn on the air conditioner, while sending "AC OFF" will turn it off. The Relay Control Unit switches the states of the appliances on and off based on the SMS commands received from the user. Finally, the system is tested thoroughly to ensure that all the components are functioning properly and the appliances are being controlled as expected. Any issues that arise during testing are addressed and resolved before the system is put into use.

System Functionality

The functionality of the system relies on multiple components working in tandem to monitor and regulate the temperature, people count, and appliances in a university laboratory. An AC-DC converter charges the battery, which powers the system components. The ESP32 Microcontroller serves as the central controller, relaying electrical signals to the relay to toggle connected appliances from OFF to ON when it receives an SMS command over the GSM network. The MLX 90614 thermometer measures the temperature through the proximity sensor, while the ESP32 Camera Module and Proximity sensor collaborate to detect people's faces entering or leaving the lab.

The face detection system's working principle combines two signals: Face detected = 1, No Face detected = 0, Body sensed by the Infrared sensor =1, and Nobody sensed by the Infrared sensor = 0. Users can send commands to the

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ESP32 Microcontroller through text messages over the GSM network. Additionally, two RPG LEDs indicate the thermometer and GSM module's operation statuses. The LCD exhibits temperature, people count, and appliance status, and the Relay Control Unit toggles the appliances from ON to OFF. A plastic box that splits into three mini-housings organizes and simplifies installation, and thorough testing ensures correct functioning before installation. Finally, the appliances link to the Relay Control Unit.

DISCUSSION

Figures 3 and 4 display the internal and external views of the proposed system, including the thermometer. The system underwent testing to evaluate its accuracy in temperature measurement and face detection. A relay control test was also conducted to ensure that the relay operated correctly and switched the appliances on and off as intended. Subsequent subsections present the outcomes of each test.

Figure 3: Internal View of the SystemFigure 4: External View of the System

Temperature accuracy test

To ensure the accuracy of temperature readings obtained from the system, a comparison test is conducted with a known temperature source, such as a reference thermometer. The system is placed in a location where temperature values are measured every 60 minutes, and these readings are compared with those obtained from the reference thermometer. The results of this comparison test over 24 hours are presented in Figure 5, demonstrating the system's ability to measure temperature accurately.

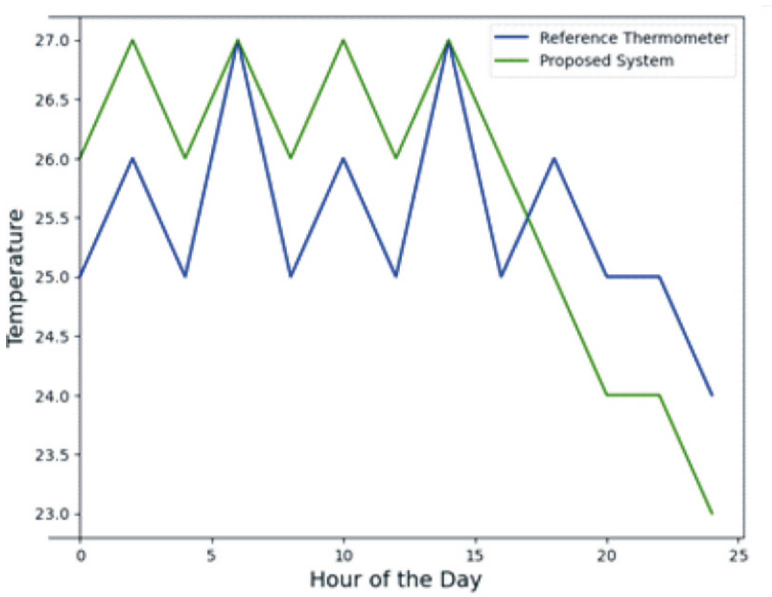

Figure 5: Observed temperature readings across the proposed system and a thermometer device.

Relay and Display test

This test involves checking if the messages and data are displayed correctly on the LCD and a test that checks if the relay is functioning correctly and turning on and off the appliances as expected. Figures 6 and 7 present the LCD and relay control test results.

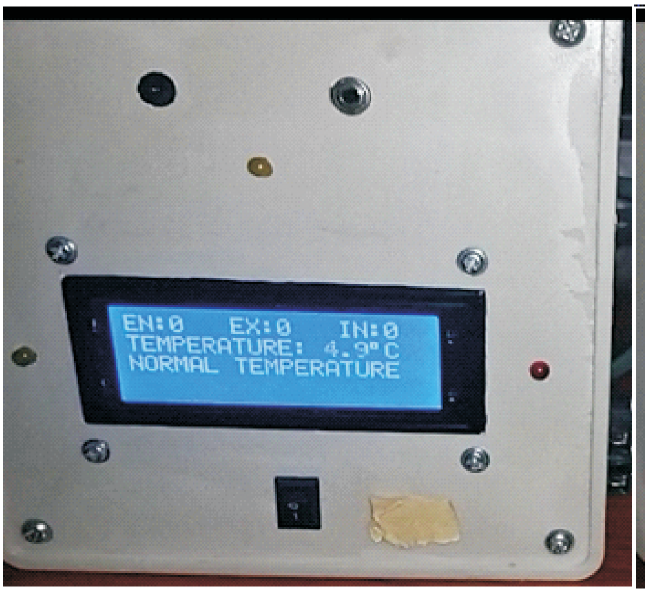

Figure 6: LCD Display of the System

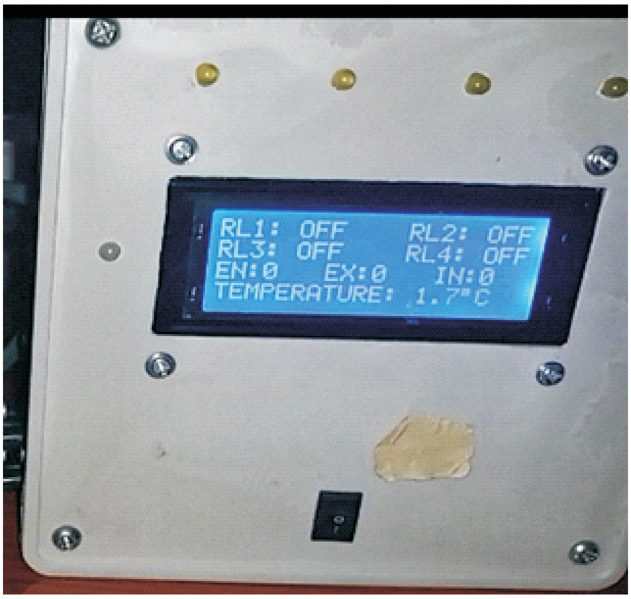

Figure 7: Relay control test

CONCLUSION

The Microcontroller-based temperature and face detection system offers a highly efficient and effective solution for monitoring temperature and detecting the presence of people in a given space. By converting Alternating Current (AC) to Direct Current (DC) and utilizing components such as the ESP32 Microcontroller board, MLX 90614 thermometer, and ESP32 Camera Module with Infrared Sensor, the system can accurately measure temperature, detect individuals, and activate appliances through the Relay Control Unit. The components are securely housed in separate mini-housings within a durable plastic box, ensuring their safety and longevity.

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