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SMART HOME AUTOMATION WITH INTEGRATED SAFETY AND SECURITY USING STM32 AND WI-FI MODULE

S Dharani Sivapriya [1], M Bhuvaneshwari [2], R Seetharaman [3]

Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Tiruchirapalli-620012, Tamil Nadu, India. [1]

Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Tiruchirapalli-620012, Tamil Nadu, India. [2]

Assistant Professor, Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Tiruchirapalli-620012, Tamil Nadu, India. [3]

Abstract: This paper presents a smart home automation system designed using the STM32F103C8T6 microcontroller and ESP8266 Wi-Fi module for efficient monitoring and control of household appliances. The system integrates multiple sensors such as an LDR for automatic lighting control, an MQ-2 gas sensor for gas leakage detection, and a DHT11 temperature and humidity sensor for monitoring ambient temperature. A 3.4 V lithium-ion battery and dual power supply units are used to distribute power to components including IR sensors, a servo motor, and other modules. The LDR detects day and night conditions and automatically controls lighting through a relay based on programmed threshold values in the microcontroller. The MQ-2 sensor identifies gas leakage and provides an alert indication, while the DHT11 sensor activates an air-conditioning relay when the temperature exceeds a predefined threshold. Additionally, two IR sensors and a servo motor are used to implement an automatic door system that opens when a person approaches and closes after passing through. A capacitive touch module is also included to allow manual door operation for safety. The proposed system provides a low-cost, efficient, and intelligent solution for home automation, improving convenience, safety, and energy management.

Keywords: Smart Home Automation, STM32F103C8T6 microcontroller, ESP8266 Wi-Fi module, MQ-2 gas sensor, DHT11 temperature and humidity sensor, LDR Sensor, IR Sensor, Servo Motor, Gas Leakage Detection, Temperature Monitoring, Automatic Door System, IoT-based Monitoring, Energy Management.

INTRODUCTION

Smart home automation has become an important application of modern embedded systems and Internet of Things (IoT) technologies. With the increasing demand for safety, energy efficiency, and convenience in residential environments, automated systems are widely used to monitor and control various home appliances. Smart systems help users manage lighting, temperature, security, and other household functions automatically without continuous human intervention. These systems improve the overall quality of living by providing intelligent control and real-time monitoring.

In this paper, a smart home automation system is designed using the STM32F103C8T6 microcontroller as the main controller and the ESP8266 Wi-Fi module for wireless connectivity with a mobile application. The system integrates several sensors and modules to perform different automation tasks. An LDR sensor is used to detect day and night conditions and automatically control lighting through a relay. A MQ-2 gas sensor is incorporated to detect gas leakage and provide immediate alerts for safety. The surrounding temperature is monitored using the DHT11 temperature and humidity sensor, which activates the air conditioning system when the temperature exceeds a predefined threshold.

In addition to environmental monitoring, the system also includes a smart door mechanism. Two IR sensors and a servo motor are used to automatically open and close the door when human movement is detected. A capacitive touch module is also integrated to allow manual door operation for additional safety and convenience. The entire system is powered using a lithium-ion battery and power supply units that distribute power to different sensors and modules.

The proposed system aims to provide an efficient, low-cost, and reliable smart home solution that enhances security, automation, and energy management in residential environments. By integrating multiple sensors and wireless communication technology, the system demonstrates how embedded systems can be effectively used for intelligent home automation applications.

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LITERATURE REVIEW

K. Swathi, G. Sravya, P. Sowmya, J. Sahithi, and L. S. Sarayu, "IoT Based Smart Home Automation System," ***International Journal for Research in Applied Science and Engineering Technology*****, vol. 11, no. 2, 2023**

This paper presents an IoT-based home automation system that allows users to control household appliances through a mobile application. The system uses sensors such as temperature and gas sensors to monitor environmental conditions and control devices automatically. The microcontroller processes sensor data and communicates with cloud platforms for remote access. The proposed system improves convenience, safety, and energy efficiency in residential environments.

S. Kumar et al., "IoT-Based Integrated Smart Home Automation System," in ***Proc. International Conference on Intelligent Systems*****, Springer, 2021.**

This research proposes a smart home system using Wi-Fi communication and environmental sensors such as LDR, gas sensors, and temperature sensors. The system continuously monitors environmental parameters and controls appliances automatically when threshold values are exceeded. A cloud server is used to store sensor data and allow remote monitoring. The system improves safety by detecting gas leakage and abnormal temperature conditions.

H. Zhang and Y. Wang, "Home Automation System Based on ESP8266," in ***Proc. IEEE International Conference on Information Technology*****, 2018.**

This study presents a low-cost home automation system using the ESP8266 Wi-Fi module. The system enables remote control of home appliances through internet connectivity and embedded web servers. Sensors and relay modules are integrated with the controller to automate lighting and other devices. The system demonstrates an efficient and scalable solution for IoT-based smart homes.

Bhaduri, M. R. Alam, A. Kumar, H. Sah, M. S. Yusuf, and A. Santra, "Seamless Home Automation with IoT Integration," ***International Journal for Research in Applied Science and Engineering Technology*****, 2025.**

This paper proposes a smart home system integrating multiple sensors such as PIR, MQ-2 gas sensor, DHT11 temperature sensor, and LDR for environmental monitoring. The system operates in both manual and automatic modes through a web interface. Sensor data is stored in cloud databases for monitoring and analysis. The solution offers an efficient and scalable approach to smart home automation.

R. Patel et al., "Smart Home Automation and Security System Using IoT," ***International Journal of Novel Research and Development*****, vol. 9, no. 5, 2024.**

This research focuses on integrating various sensors such as motion sensors, gas sensors, and temperature sensors with IoT platforms for real-time monitoring. The system enables remote control of home appliances through mobile applications. It also provides alerts for security threats such as gas leakage or motion detection. The proposed system enhances safety and convenience for homeowners.

S. Sharma and P. Gupta, "Intelligent Home Automation Using IoT," ***International Journal for Research in Applied Science and Engineering Technology*****, 2022.**

This paper describes an intelligent home automation system using NodeMCU and relay modules to control electrical appliances. The system integrates sensors to detect environmental conditions and automatically control devices. It also includes safety mechanisms such as fire detection and automated alarm systems. The study highlights the importance of IoT in improving residential safety and efficiency.

M. M. Islam, S. Nooruddin, F. Karray, and G. Muhammad, "Internet of Things Device Capabilities, Architectures, Protocols, and Smart Applications," ***IEEE Access*****, 2022.**

This review paper discusses IoT architectures, protocols, and hardware platforms used in smart applications including smart homes. It explains how microcontrollers such as ESP8266 and embedded sensors enable intelligent monitoring and

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automation. The study also analyzes communication protocols like MQTT and CoAP used in IoT systems. The paper provides insights into designing scalable IoT-based automation systems.

S. A. Mozumder and A. S. M. S. Sagar, "IRHA: Intelligent RSSI-Based Home Automation System," ***arXiv preprint,*** **2022.**

This paper proposes a location-aware home automation system that uses Wi-Fi signal strength (RSSI) to identify user location inside a home. Machine learning algorithms classify Wi-Fi signals to determine the user's room and automatically control appliances. The system achieved high accuracy in location detection and improved automation efficiency.

Kumar and P. Singh, "Sensor-Based Smart Home Automation System," ***International Journal of Scientific Research and Engineering Development,*** **vol. 8, no. 2, 2025.**

This paper presents a smart home system using sensors such as LDR, DHT11, and MQ-2 integrated with microcontrollers. The system monitors environmental parameters and controls electrical appliances through relay modules. The design ensures safe switching of high-voltage devices while maintaining low-power operation. The system demonstrates improved safety and energy efficiency

D. Bouchabou, S. M. Nguyen, C. Lohr, B. Leduc, and I. Kanellos, "Human Activity Recognition in Smart Homes Based on IoT Sensors," ***IEEE Access,*** **2021.**

This study reviews different IoT sensor-based methods used for monitoring human activities inside smart homes. The research discusses algorithms and techniques used to detect user movements and automate household devices. It also highlights challenges in smart home systems such as data processing and sensor accuracy. The work emphasizes the importance of intelligent automation in modern homes.

PROBLEM STATEMENT

Modern homes require efficient systems to ensure safety, energy management, and convenience for users. Traditional home systems mainly depend on manual operation, which can lead to problems such as unnecessary power consumption, delayed response to hazardous situations like gas leakage, and lack of security monitoring. In many households, lighting systems remain switched on even during daytime, gas leaks may go unnoticed, and temperature changes are not automatically controlled, which may affect both safety and comfort. In addition, conventional door systems require manual operation, which reduces convenience and may not provide adequate security.

To address these issues, there is a need for an intelligent and automated system capable of monitoring environmental conditions and controlling home appliances automatically. By using embedded systems such as the STM32F103C8T6 microcontroller along with wireless communication through the ESP8266 Wi-Fi module, it is possible to integrate sensors like LDR, gas sensors, temperature sensors, and motion sensors to develop a smart home solution. Therefore, the problem addressed in this work is the design and implementation of a low-cost, reliable, and efficient smart home automation system that can automatically control lighting, detect gas leakage, monitor temperature, and operate doors while providing improved safety, energy efficiency, and user convenience.

SYSTEM DESIGN AND METHODOLOGY

The core of the system is the STM32F103C8T6 microcontroller, which acts as the main controller responsible for processing sensor data and controlling different devices. The ESP8266 Wi-Fi module is integrated with the microcontroller to enable wireless communication between the prototype and a mobile application. Various sensors are connected to the microcontroller to monitor environmental conditions. An LDR sensor is used to detect the intensity of light and determine whether it is day or night. Based on the threshold value programmed in the controller, the system automatically switches the lighting through a relay connected to a bulb.

For safety monitoring, an MQ-2 gas sensor is used to detect gas leakage inside the home. When gas concentration exceeds the preset limit, the system detects the leakage and provides an alert indication. The surrounding temperature is

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continuously monitored using the DHT11 temperature and humidity sensor. When the temperature exceeds the predefined threshold value, the microcontroller activates a relay that simulates switching on an air conditioning system.

The system also includes an automatic door mechanism. Two IR sensors are placed near the door to detect human presence and movement. When the first IR sensor detects a person approaching the door, the microcontroller sends a signal to a servo motor to open the door. After the person passes through, the second IR sensor detects the movement and triggers the servo motor to close the door. Additionally, a capacitive touch module is integrated to allow manual door operation for safety and convenience.

The entire system is powered using a 3.4 V lithium-ion battery and two power supply units to distribute power effectively to sensors, motors, and other electronic components.

HARDWARE DESIGN

The hardware design of the proposed smart home automation system is developed by integrating sensors, actuators, communication modules, and a microcontroller to perform monitoring and automation tasks. The main controller used in the system is the STM32F103C8T6 microcontroller, which processes the input signals received from different sensors and controls the output devices. The system also incorporates the ESP8266 Wi-Fi module to enable wireless communication between the hardware prototype and the mobile application.

In the hardware setup, an LDR sensor is connected to the microcontroller to detect ambient light intensity. When the light level falls below a predefined threshold value, the controller activates a relay to switch on a bulb connected to the AC power source. Similarly, an MQ-2 gas sensor is used to detect gas leakage inside the house. When the sensor detects gas above the safe limit, the microcontroller processes the signal and indicates the presence of gas leakage for safety purposes.

The surrounding temperature is monitored using the DHT11 temperature and humidity sensor. When the temperature exceeds the programmed threshold value, the microcontroller activates a relay that simulates switching on an air conditioning system. For door automation, two IR sensors are placed near the door to detect human movement. When the first IR sensor detects a person approaching the door, the controller sends a signal to the servo motor to open the door. After the person passes through, the second IR sensor detects the movement and the microcontroller commands the servo motor to close the door.

Additionally, a capacitive touch module is integrated into the system to allow manual door operation for safety and convenience. The entire hardware system is powered using a 3.4 V lithium-ion battery along with two power supply units that distribute power to sensors, relay modules, and the servo motor. This hardware configuration enables reliable monitoring, automation, and control of household devices in the proposed smart home system.

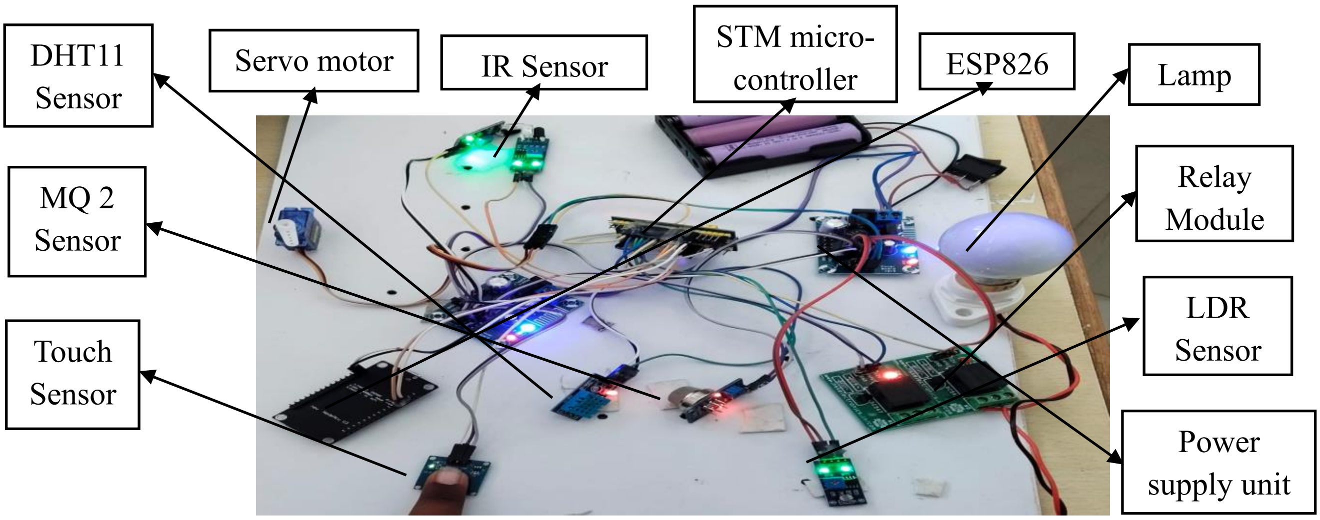

Figure 1.1: Hardware design

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SOFTWARE IMPLEMENTATION

The software implementation of the proposed smart home automation system is responsible for controlling sensors, processing data, and operating different devices based on predefined conditions. The program for the system is developed and uploaded to the STM32F103C8T6 microcontroller using an embedded development environment. The microcontroller continuously reads input data from the connected sensors and executes the control logic programmed in the system.

Initially, the microcontroller is configured to initialize all input and output pins connected to sensors, relay modules, and the servo motor. The program continuously reads data from sensors such as the LDR, IR sensors, gas sensor, and temperature sensor. The LDR sensor detects the surrounding light intensity, and the microcontroller compares this value with a predefined threshold level. If the light intensity is lower than the threshold value, the controller activates the relay to switch on the bulb; otherwise, the light remains off.

For safety monitoring, the system reads the signal from the MQ-2 gas sensor to detect gas leakage. When the detected gas concentration exceeds the safe limit, the system indicates the presence of gas leakage. Similarly, the DHT11 temperature and humidity sensor continuously measures the surrounding temperature. When the temperature value crosses the programmed threshold, the microcontroller activates the relay to simulate turning on the air conditioning system.

The software also controls the automatic door mechanism. The program monitors the signals from two IR sensors placed near the door. When the first IR sensor detects a person approaching, the controller sends a signal to the servo motor to rotate and open the door. When the second IR sensor detects the person leaving, the controller commands the servo motor to return to its initial position, thereby closing the door. Additionally, the capacitive touch module allows manual door control, which is also handled by the microcontroller program.

Wireless communication is established using the ESP8266 Wi-Fi module, which allows the system to connect with a mobile application for monitoring and control purposes. Through this software implementation, the system ensures automatic operation, improved safety, and efficient management of home appliances.

FLOW OF OPERATION

The operation of the proposed smart home automation system begins when the power supply is turned on and all the hardware components are initialized by the STM32F103C8T6 microcontroller. The microcontroller continuously monitors input signals from different sensors integrated into the system. The LDR sensor first detects the surrounding light intensity to determine whether it is day or night. If the light level falls below the predefined threshold value, the microcontroller activates a relay to switch on the lighting system; otherwise, the light remains off. At the same time, the MQ-2 gas sensor continuously monitors the environment for gas leakage. If gas concentration exceeds the safe limit, the system detects the leakage and indicates the presence of gas. The surrounding temperature is also monitored using the DHT11 temperature and humidity sensor, and when the temperature rises above the preset threshold value, the microcontroller activates the relay to simulate turning on the air conditioning system. For the automatic door mechanism, two IR sensors are installed near the entrance. When the first IR sensor detects a person approaching the door, the microcontroller sends a signal to the servo motor to open the door. After the person passes through, the second IR sensor detects the movement and commands the servo motor to close the door. Additionally, a capacitive touch module allows the user to manually open the door when required. Throughout the operation, the ESP8266 Wi-Fi module provides wireless connectivity for monitoring and communication with the mobile application. This sequence of sensing, processing, and actuation enables the system to perform automated home control efficiently.

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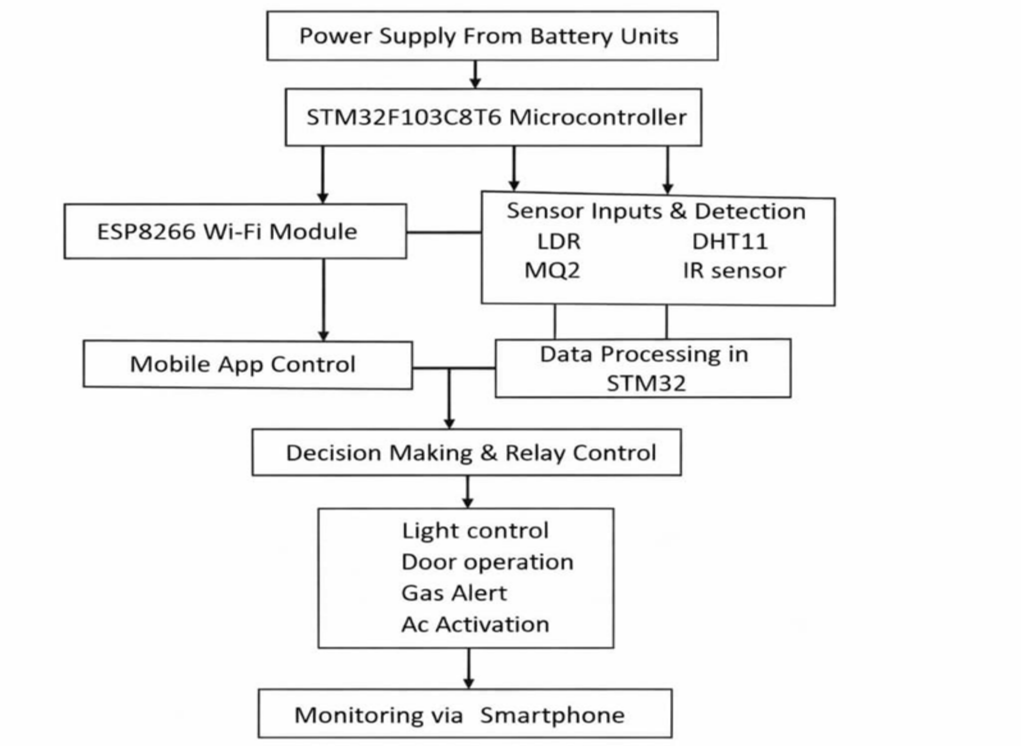

Figure 1.2: Flowchart

IMPLEMENTATION OPERATION

The implementation of the proposed smart home automation system involves the integration of hardware components and software programming to achieve automatic monitoring and control of household devices. Initially, all required components such as sensors, microcontroller, communication modules, relays, and actuators are selected and assembled on the prototype. The main controller used in the system is the STM32F103C8T6 microcontroller, which acts as the central processing unit for collecting sensor data and controlling different devices.

In the first stage, sensors including the LDR sensor, IR sensors, gas sensor, and temperature sensor are connected to the input pins of the microcontroller. The LDR sensor is used to detect the surrounding light intensity for automatic lighting control, while the MQ-2 gas sensor is connected to detect gas leakage in the home environment. The DHT11 temperature and humidity sensor is interfaced with the microcontroller to monitor ambient temperature. Two IR sensors are installed near the door to detect human movement for the automatic door mechanism.

In the next stage, output devices such as relay modules and a servo motor are connected to the microcontroller. The relay modules are used to control electrical appliances such as lights and the air conditioning system. The servo motor is connected to operate the automatic door opening and closing mechanism. A capacitive touch module is also integrated into the system to allow manual control of the door for safety purposes.

After completing the hardware connections, the software program is developed and uploaded to the microcontroller to control the operation of all sensors and actuators. The program continuously reads the sensor data, compares it with predefined threshold values, and performs appropriate actions such as switching on lights, detecting gas leakage, activating the AC relay, or operating the door.

Finally, the ESP8266 Wi-Fi module is integrated to enable wireless communication between the system and the mobile application. The entire system is powered using a lithium-ion battery and power supply units to ensure stable operation of all components. Through this implementation process, the proposed system achieves efficient home automation with improved safety, convenience, and energy management.

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RESULTS

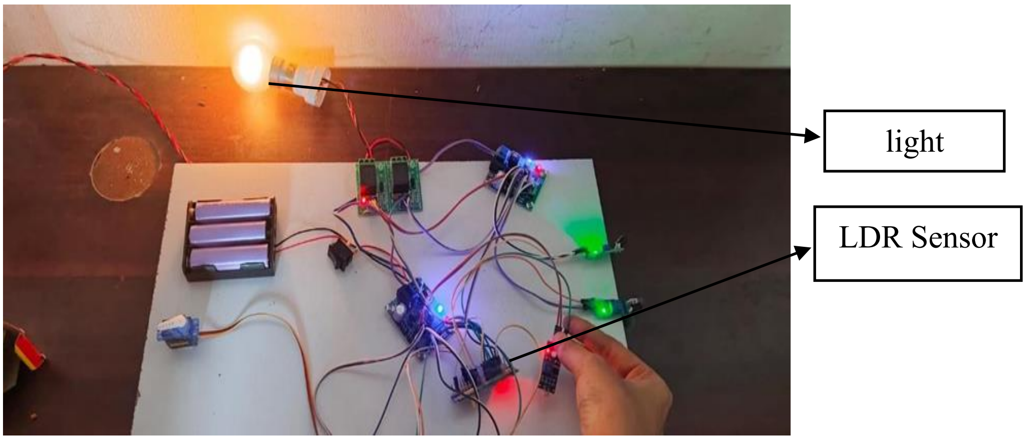

Figure 1.3: Output through automation mode

In automatic mode, the LDR sensor measures the surrounding light intensity and sends the corresponding analog signal to the STM32F103C8T6 microcontroller. When the detected light level falls below a predefined threshold (indicating night conditions), the microcontroller triggers the control circuit, which switches ON the lamp via the relay module. This ensures automatic lighting control based on environmental light conditions.

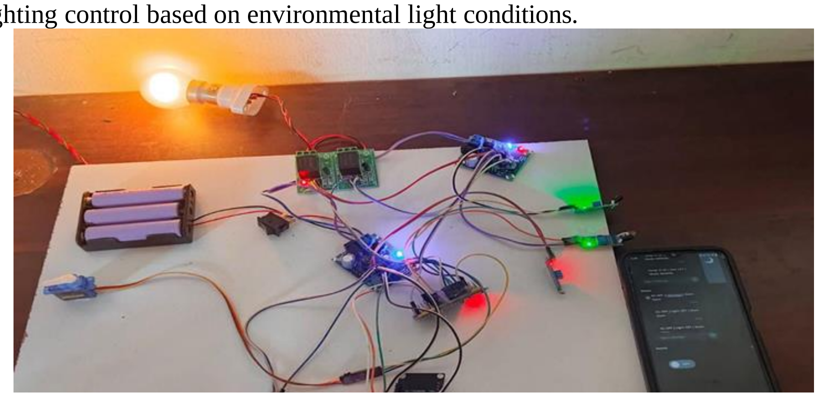

Figure 1.4: Output through manual mode

In manual mode, the lamp can be controlled directly through the mobile application. When the user touches the 'Light ON' option in the mobile app, a command is transmitted through the ESP8266 Wi-Fi module to the microcontroller. The microcontroller processes this command and activates the relay module, which turns ON the connected lamp. This demonstrates real-time remote control of the lighting system using a smartphone interface, allowing the user to manually operate the device regardless of the environmental conditions.

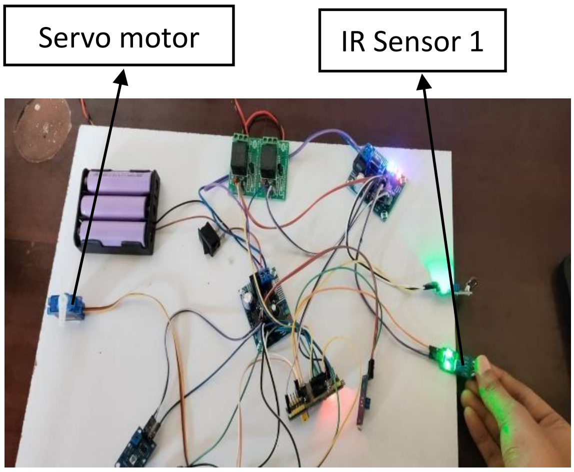

Figure 1.5: Door open (Servo motor)

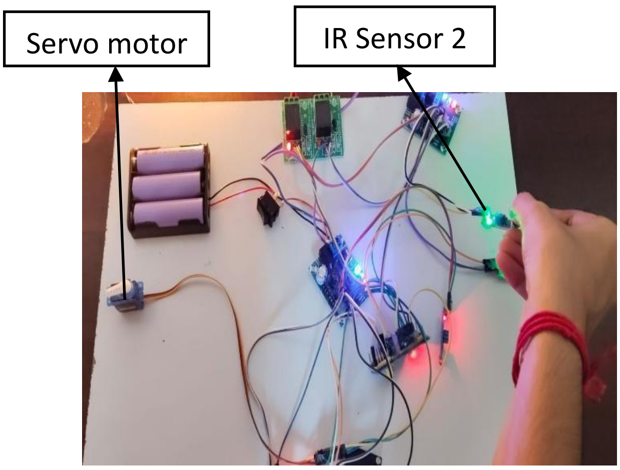

Figure 1.6: Door closed (Servo motor)

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The system uses two IR sensors to automatically control the opening and closing of the door. When IR Sensor 1 detects an obstacle, such as a person approaching the entrance, it sends a signal to the microcontroller, which processes the input and activates the servo motor to rotate and open the door, enabling automatic access without manual intervention. After the object passes through, IR Sensor 2 detects the movement and sends a signal to the microcontroller, which then commands the servo motor to return to its initial position, thereby closing the door. This dual-sensor configuration ensures smooth and efficient door operation, providing reliable entry and exit control in the smart automation system.

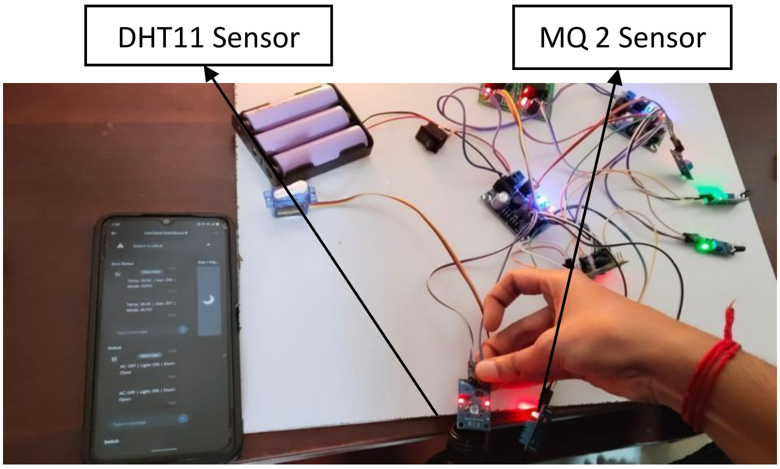

Figure 1.7: Gas leakage and temperature control output

When the MQ2 gas sensor detects the presence of gas leakage, the microcontroller processes the sensor signal and sends a notification to the mobile application through the IoT interface. The application then displays a gas leakage alert to inform the user immediately.

At the same time, the DHT11 sensor continuously monitors the surrounding temperature. When the detected temperature exceeds the predefined threshold value, the microcontroller automatically activates the air conditioning (AC) system through a relay module. The relay indicator LED turns ON, confirming that the AC has been successfully activated. This status is also reflected in the mobile application, providing real-time monitoring of the system operation.

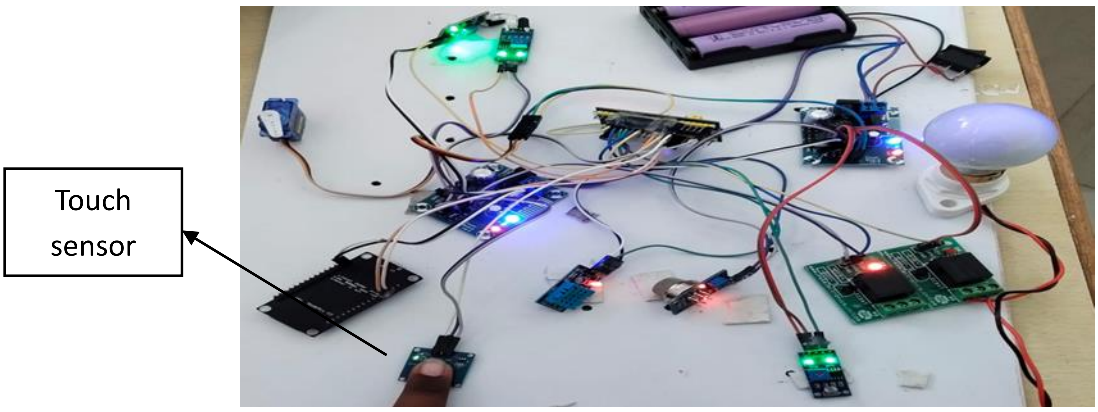

Figure 1.8: Touch sensor detects human touches

A touch sensor detects human touch using changes in capacitance or electrical signals when a finger comes close or contacts the surface. When touched, it sends a digital output signal (HIGH/LOW) to the microcontroller indicating the touch event.

CONCLUSION

This paper presented a smart home automation system that integrates multiple sensors and control modules to improve safety, convenience, and energy efficiency in residential environments. The system is designed using the

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STM32F103C8T6 microcontroller as the main controller along with the ESP8266 Wi-Fi module for wireless connectivity. Sensors such as the MQ-2 gas sensor, DHT11 temperature and humidity sensor, LDR sensor, and IR sensors are used to monitor environmental conditions and detect human presence. Based on the sensor inputs, the system automatically controls lighting, detects gas leakage, monitors temperature, and operates an automatic door using a servo motor. The proposed system demonstrates a low-cost, reliable, and efficient approach to home automation, providing enhanced safety, improved energy management, and increased user convenience.

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