Smart home automation using internet of things

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ABSTRACT

This research paper delves into the development and implementation of an advanced home automation system utilizing internet of things (IoT) technology to bolster safety and comfort within residential environments. The proposed system architecture revolves around an ESP8266 microcontroller board interfaced with a diverse array of sensors, including motion detectors, temperature and humidity sensors, and air quality sensors specifically designed to detect gas leaks. Additionally, the system incorporates a servo motor for stove control and relays for fan activation. The described system adds novel safety-focused features, including servo-controlled stoves and fan-gas leak integration, making it applicable for critical home safety scenarios. However, it shares common weaknesses with existing systems, such as inadequate attention to security, energy efficiency, and scalability. By addressing these gaps, this system could set itself apart as a comprehensive IoT solution for home automation.

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1. INTRODUCTION

Advancements in technology have completely transformed how we engage with our living spaces. The internet of things (IoT) is leading this charge, ushering in an era defined by connectivity, automation, and unparalleled control. Central to this technological revolution is home automation—a game-changing approach that integrates smart devices and appliances to craft intelligent living environments [1]-[3].

Home automation essentially harnesses the power of interconnected devices to offer users a unified and seamless method of overseeing various aspects of their homes [4], [5]. From lighting that adjusts to our preferences to climate control systems that anticipate our needs, the smart home ecosystem streamlines daily routines, boosts efficiency, and enhances overall quality of life. The market is flooded with different kinds of devices that enable home automation. While a majority of them focus on appliance control through apps, or more recently, voice control, there is a lot more that can be accomplished through automation [6].

The intricate network of devices composing a "Smart Home Automation" system goes beyond mere convenience; it symbolizes the fusion of cutting-edge technology with the pursuit of a more sustainable lifestyle. By empowering users to remotely manage and monitor their home environment, this system breaks traditional boundaries, enabling interaction and management of homes from virtually any corner of the globe.

A lot of working prototypes have been made using Raspberry Pi and Arduino boards. This work has been designed keeping in mind everyday use cases and cost to implement, manufacture and operate. Multiple cloud services are available for this project and Blynk IoT was chosen for its ease of use and functionality. ESP dash was also used for certain part of the project where there were some un favorable conditions.

This paper presents a working low-cost model that can implement the basics of home IoT as well as be scaled up as per the requirements needed. The main control system is the ESP8266 mini board that can be set up in two different ways based on the requirements. One would be connecting the main board to the Wi-Fi network available and another would be to create its own network. The sensors read in data and constantly update the dashboard. Other automations are implemented that involve these sensor readings.

The rest of the paper is organized as follows: section 2 presents the related work that exists and similarities. The proposed methodology is presented in section 3 and in section 4 the results are presented. Section 5 holds the conclusion of the research and section 6 has information about future enhancements of the project.

The collection of work available has explored a diverse range of methodologies and technologies. Papers [1]-[4] delve into the practical implementation of Arduino and Raspberry Pi platforms, showcasing their versatility in enabling remote control and optimizing energy usage. These works not only demonstrate the technical feasibility of such systems but also underline their potential for real-world applications in homes and offices alike.

Raju *et al.* [3] delve into the integration of advanced technologies like machine learning and deep learning. Raju *et al.* [3], explores the use of machine learning for predicting energy loads, enhancing efficiency. Mandula *et al.* [7], focuses on deep learning for bolstering security measures through facial recognition. These contributions underscore a shift towards intelligent home automation systems capable of adapting to user needs and environmental changes dynamically.

Vagdevi *et al.* [8], Nirmala *et al.* [9] present innovative approaches to home automation. Vagdevi *et al.* [8] explores the use of near field communication (NFC) for appliance control, while Nirmala *et al.* [9] proposes a web-based interface for remote monitoring. These works expand the horizon of possibilities within home automation, offering novel solutions catering to diverse user preferences. As the field continues to evolve, these contributions serve as valuable stepping stones towards creating smarter, more responsive living environments that enhance convenience, efficiency, and security in our daily lives.

Mustafa *et al.* [10] propose an IoT framework that integrates sensors, embedded controllers, and cloud connectivity for real-time monitoring and automated control in intelligent systems, emphasizing efficient data acquisition and decision-making. Rao *et al.* [11] develop a secure IoT-based smart home automation system for real-time environmental monitoring and remote appliance control, focusing on security, reliability, and safe operation.

The papers [12]–[15] discuss IoT-based smart home systems and safety solutions. Gota *et al.* [12] and Singh and Ansari [13] propose Arduino- and IoT-based frameworks for automated appliance control and remote monitoring. Kadiyan *et al.* [14] further explore IoT-enabled home automation for real-time device management. Tamaki and Premachandra [15] present a low-cost, energy-efficient reminder system to detect unextinguished gas stoves, emphasizing safety enhancement.

The papers [16]–[25] focus on advanced IoT-based smart home automation, emphasizing cloud integration, enhanced security, energy efficiency, and intelligent control. Several studies address secure architectures and threat mitigation, including blockchain-based solutions and comprehensive security surveys. Others propose energy-efficient automation using machine learning, voice-controlled systems, and ESP32-based implementations. Recent works highlight artificial intelligence (AI)-enabled smart home architectures and applications, demonstrating scalable and intelligent automation frameworks.

2. METHOD

The main objectives of the work is to implement a seamless automation and connectivity between the appliances and the user while also taking care of the security and safety concerns. Figure 1 shows the flow chart of the proposed model and how all the components are conditioned to interact with each other. The system begins by initializing the controller and continuously reading values from multiple sensors, including a smoke sensor, a temperature sensor, and a passive infrared (PIR) sensor. Under normal operating conditions, all kitchen appliances are allowed to remain ON. The sensor data is periodically processed and displayed on a monitoring dashboard, enabling real-time observation of environmental conditions around the cooking area.

Figure 2 shows the block diagram hat illustrates the functional architecture of the smart kitchen safety system. The mobile application, such as Blynk or ESP dash, serves as the user interface for real-time monitoring and alert notifications, with data communication handled through the Blynk cloud server. The ESP8266 controller (Wemos D1 Mini) acts as the central processing unit, collecting inputs from sensors including the DHT11 for temperature and humidity, the MQ135 for gas or smoke detection, and the PIR sensor for human presence. Based on this sensor data, the controller operates the actuators—relay, servo motor, and buzzer—to control appliances, manage ventilation, and trigger alarms, thereby enabling automated and reliable safety control.

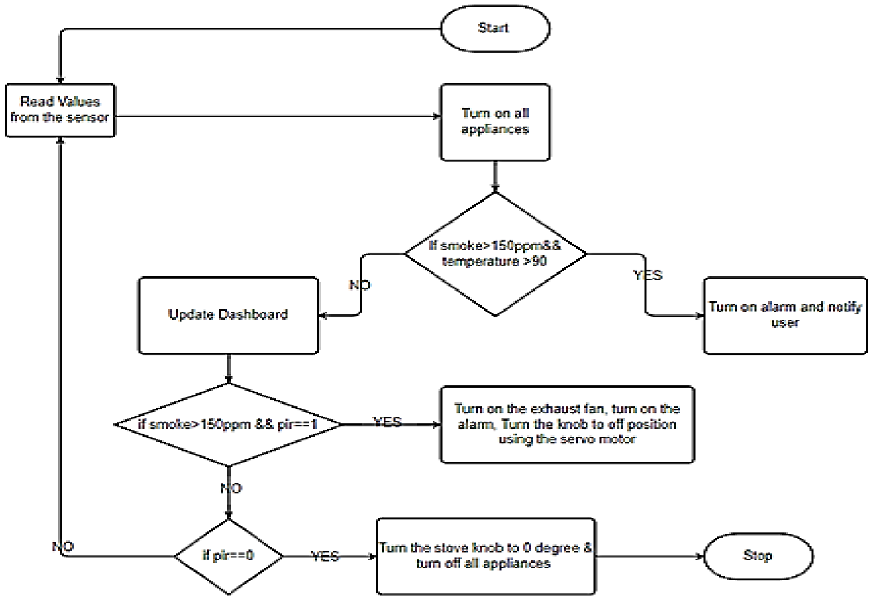


Figure 1. Flow chart

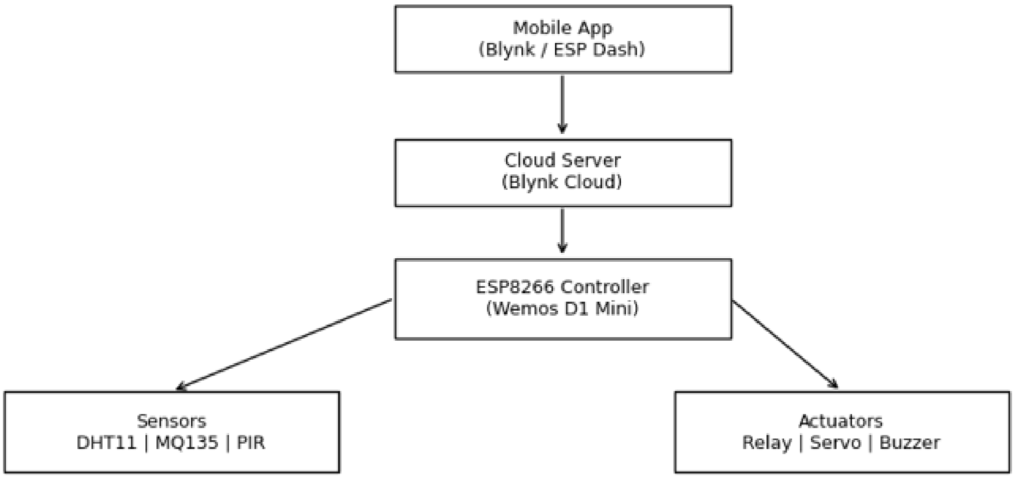


Figure 2. System architecture diagram-smart home automation

The system first reads values from the sensors and turns ON all appliances. It then checks whether the smoke concentration exceeds 150 ppm and the temperature is above 90 °C; if this condition is satisfied, the alarm is activated to notify the end user, otherwise the sensor readings are updated on the dashboard. From the dashboard, the system again verifies the sensor status: if the smoke level is greater than 150 ppm and the PIR sensor value is 1 (human presence detected), the exhaust fan is turned ON, whereas if the PIR sensor value is 0 (no human presence), all other appliances are turned OFF to ensure safety.

A critical decision point in the flowchart checks whether the smoke concentration exceeds 150 ppm and the temperature rises above 90 °C. These thresholds indicate a potentially dangerous situation such as a fire or gas leakage. When this condition is satisfied, the system immediately activates an alarm and sends a notification to the user, thereby providing an early warning and allowing quick human intervention to prevent accidents.

In another safety scenario, the system evaluates whether smoke levels are high while human presence is detected through the PIR sensor. If smoke is present and a person is nearby, the controller automatically turns ON the exhaust fan to disperse smoke or gas, activates the alarm, and rotates the stove knob to the OFF position using a servo motor. This automated response minimizes risk by cutting off the gas supply while simultaneously improving ventilation.

The system also handles situations where no human presence is detected near the stove. If the PIR sensor indicates the absence of a person, the controller assumes that the stove may have been left unattended. In such cases, the stove knob is turned to the zero-degree (OFF) position and all connected appliances are switched OFF, ensuring energy conservation and preventing fire hazards due to negligence.

In the Figure 3, explains about the entire model operates using the data collected from various sensors. These sensors continuously capture real-time information from the environment, and this input becomes the primary driver of the system’s behavior. Based on these sensor readings, an embedded automation algorithm processes the data, interprets the conditions, and triggers the appropriate actions. In essence, the model’s performance and decision-making depend entirely on the quality and accuracy of the sensor inputs, as well as the logic defined within the automation algorithm.

Overall, the proposed system integrates sensing, decision-making, and actuation to enhance kitchen safety. By combining real-time monitoring with automated control and alerts, the system significantly reduces the risk of fire, gas leakage, and unattended cooking, making it a practical and effective solution for smart home and safety-critical applications.

A. Hardware

As Figure 3 shows, multiple hardware components have been made use of. The hardware components used within the system are:

– Wemos D1 mini ESP8266
– Temperature and Humidity sensor DHT11
– Gas sensor MQ135
– PIR sensor
– SG 90 servo motor
– 4 channel relay
– Breadboard

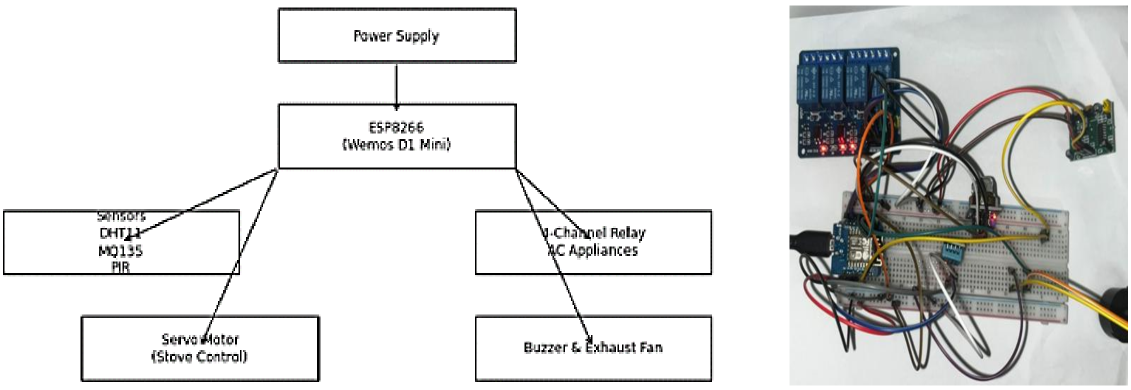


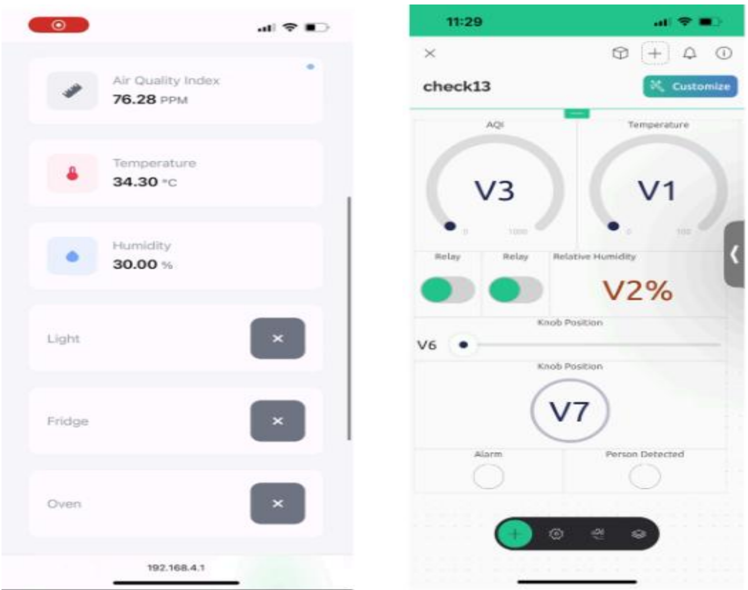
Figure 3. Hardware implementation

B. Software

For programming the Wemos board, the Arduino ide software version 2.3.2 was used. And for the dashboard, two options were explored namely ESP dash and Blynk cloud. Blynk cloud turned out to be more feature rich and satisfied the expectations and requirements.

– The AC appliances: the alternating current appliances are connected and controlled by a 4 channel relay. The switches have been set up to match the pins on the board in the digital dashboard that is used. One of the appliance is the exhaust fan that is completely automated and no manual control is provided for it. The exhaust fan turns on as and when a gas leak is detected and the alarm is triggered. Rest all other appliances can be manually controlled by the user either through a physical switch or through the dashboard using the Blynk app on their mobile device.
– The sensors: the sensors are connected to certain digital pins on the Wemos board and are configured to input mode. The infrared sensor sends a high signal if it detects any sort of motion and low signal if there is no motion detected. Whereas the temperature sensor and the gas sensor read in valuable information like the temperature, humidity and the air quality index as and when there is a change detected. Based on these changes detected if it crosses a certain predefined threshold, the exhaust fan, the buzzer is activated and the stove knob turns to the off position.

- The servo motor: the sg90 servo motor is configured in such a way that it always updates the stove's knob position on the dashboard and it is directly attached to the knob. If the user leaves the kitchen and if no motion is detected by the PIR(infrared) sensor but if the stove is on, the servo motor kicks in to turn the knob back to off or 0 degrees. If there is no user detected by the PIR sensor but yet the system receives a command to update the knob or turn on the gas stove, it reverts back to zero thereby preventing a gas leak caused by human error as shown in Figure 4.
- The Buzzer: Buzzer is coded in such a way that if there is any sort of fire or gas leak irrespective of the user being in the kitchen or the vicinity, it starts buzzing.
- Dashboard: there are two ways to implement the dashboard. The first method would be to use this dashboard called ESP dash as shown in Figure 4(a). The alternate method would be to use Blynk cloud platform as shown in Figure 4(b). The alternate method is preferred over the original method as it offers a lot more features and flexibility. It also allows the user to control or monitor the system when not connected to the same network as the system. Whereas in ESP dash it is required to be connected to the same network as the system in order to monitor and control it. The Blynk cloud platform allows manual control of the sg90 servo motor as well, the controls of which were lacking in the ESP dash platform. Overall, the data streams can be managed and edited using the Blynk cloud website and the mobile application which can run on both iOS and latest Android operating systems. The ESP dash platform in Figure 4(a) required the user to either connect to the soft ap(Wi-Fi hotspot) provided by it or stay on the same Wi-Fi network its configured to. Hosts the web server locally and is not connected to the internet.



(a) (b)

Figure 4. Safety reset mechanism when no user is detected by the PIR sensor (a) ESP dashboard on mobile and (b) Blynk app dashboard

3. RESULTS AND DISCUSSIONS

After the entire system was set up and coded, it was subjected to multiple levels of testing ranging from unit testing, integration testing to system testing. Some components were found to be faulty and were hence promptly replaced. Some had a loose wiring issue on the breadboard which was isolated and fixed as and when detected. The dashboard were tested based on their functionalities.

Figure 5 shows the overall layout of the Blynk application running on an iOS device. The first row consists of two guages temperature and AQI. The second row consists of switches that control the AC devices and the percentage of the relative humidity in the room. The Figure 5 also shows how the mobile device is actually not connected to a Wi-Fi network and still gets real time sensor data through the internet. It also has two led's on the bottom row that shows if the alarm is triggered or if human is detected.

Figure 5 shows how when the knob is turned 55 degrees, the position is also updated in real time. This happens only when a person is detected near the stove or inside the room. Below the knob position, a real-time graph of temperature and humidity variations are being shown.

Figure 5. Temperature, relative humidity and AQI

Figure 6 shows the live graph visualization on the mobile device for the temperature and humidity variations. This is possible through the use of Blynk application. Multiple graphs like these can be setup based on the data streams available on the Blynk cloud. The hardware and software decide the maximum number of data streams. The bandwidth also makes a difference while loading all the sensor information from the board to the dashboard. If there are multiple sensors, it will increase the bandwidth usage and might take time to load. In this case sometimes the graph might be empty or might take time to load. Figure 7 shows when the device went offline and when it came back online using a neat graphical interface. Some level of endurance testing was done as seen in the logs. The results have been summarized in the Table 1.

Figure 6. Live graph

Overall, the graphs in Figure 8 demonstrate continuous monitoring of environmental and system parameters such as temperature, gas concentration, humidity, servo position, exhaust fan state, and alarm status. The given graph in Figure 8(a) shows a gradual increase in temperature and a faster rise in gas concentration over time, along with their safety thresholds. When the values exceed 90 °C and 150 ppm, the system detects a hazardous condition and activates safety measures.

The graph in Figure 8(b) shows the variation of relative humidity over time, fluctuating in a smooth, wave-like pattern between approximately 50% and 60%. This indicates periodic changes in ambient moisture levels, which can be useful for monitoring indoor environmental comfort and safety conditions. The graph in Figure 8(c) shows normal operation with the servo at about 55° and the exhaust fan OFF. When a hazard is detected, the servo turns to 0° to switch OFF the stove, and the exhaust fan turns ON for safety. The graph 8(d) shows alarm remains OFF during normal operation and turns ON instantly when a hazardous condition is detected, alerting the user.

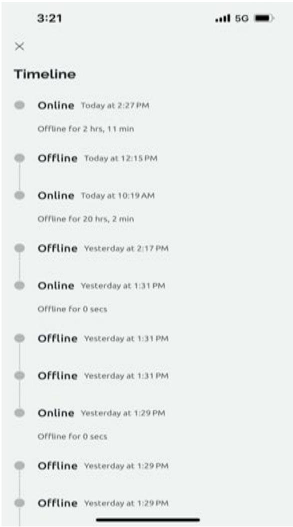


Figure 7. Device status logs

Table 1. Device function with outcome result

Function tested	Simulated condition	Expected outcome	Observed outcome	Status
Sensor data update	Normal environment	Correct dashboard display	Accurate real-time display	Pass
Motion detection	PIR = 1	Motion detected	Motion detected	Pass
Gas leak alert	MQ135 > 150 ppm	Alarm ON	Alarm ON	Pass
Exhaust fan control	Gas + human presence	Fan ON	Fan ON	Pass
Automatic stove OFF	No motion detected	Stove OFF	Stove OFF	Pass

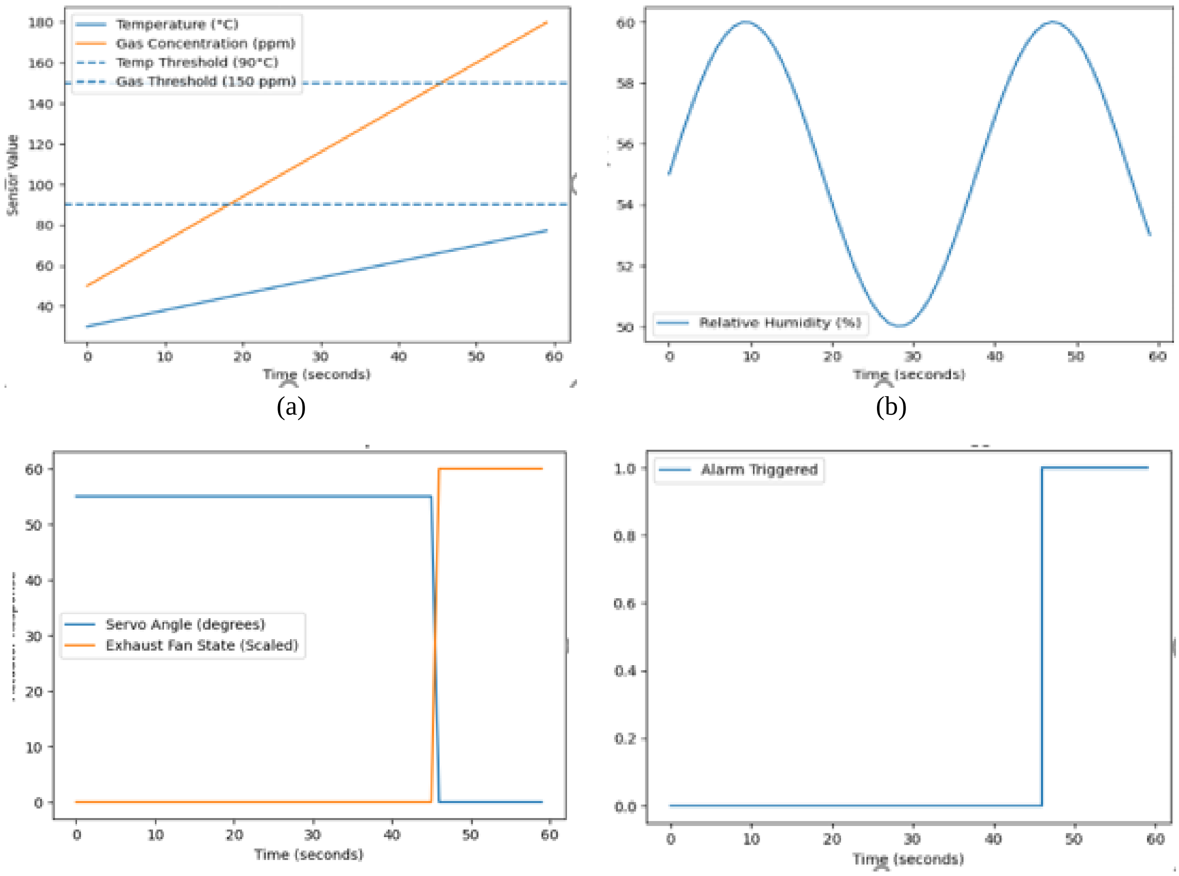


Figure 8. Simulation result (a) temp and gas concentration, (b) humidity variation, (c) actuator response to gas leak, and (d) alarm trigger timeline

4. CONCLUSION

The home automation project incorporating an ESP8266 board and various sensors has successfully demonstrated the feasibility and effectiveness of enhancing kitchen safety through smart technology. By leveraging IoT principles, the system offers proactive measures to mitigate potential hazards, such as gas leaks and overheating. Moving forward, further refinements and enhancements could be made to improve the system's accuracy and responsiveness. This could include fine-tuning sensor calibration, implementing machine learning algorithms for predictive analysis, and expanding compatibility with additional smart home devices for seamless integration and control. Overall, the project underscores the potential of IoT technology in revolutionizing home safety and convenience, paving the way for smarter and more secure living environments.

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Roopa R.	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	
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Kashish Agarwal		✓				✓	✓	✓		✓	✓			

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, R Roopa, upon reasonable request

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