Design and Implementation of a Smart Home Security System Using Multiple Sensors and IoT

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Abstract- ***As the demand for home security and safety increases, traditional security systems have reduced efficacy due to slow responses and limited monitoring options. The paper presents a smart home security system based on multiple sensors and IoT technology for more safety, energy efficiency, and convenience. Ultrasonic sensors detect visitors at the door, PIR motion sensors track movement inside the house, and an MQ2 gas sensor detects smoke and gas leakage. An LDR-laser setup detects unauthorized entry. Light and door can be automated via the LED and servo motors. An Arduino microcontroller processes the sensor data, whereas the ESP32 module provides real-time alerts to the homeowner's mobile device. Experimental results show that the system reacts instantly to possible threats, gives reliable notifications concerning intrusions, and is energy efficient. Therefore, this project presents a low-cost, scalable, and easy-to-use design for modern smart homes.***

Keywords: Smart Home Security, IoT, Arduino, ESP32, Ultrasonic Sensor, Motion Sensor, Gas Detection, Automation

I. INTRODUCTION

In the present era of fast life, home security is considered to be of utmost importance. The traditional security systems require some monitoring by people or manual intervention, which is always slow and sometimes inefficient in preventing mishaps or intrusion. Technology has paved the way for safe home systems, providing a more effective, automated, and reliable approach toward home safety.

This paper discusses the smart home security system that incorporates various sensors attached via IoT to ensure complete monitoring and controlling functionalities. The system is constructed with an ultrasonic sensor that is supposed to detect any visitors at the door and PIR motion sensors to monitor movement inside the house. An MQ2 gas sensor identifies smoke or gas leaks; a laser-LDR setup detects intruders. Be- sides, an automated lighting system will be provided through LEDs, with a servo motor allowing remote-controlled opening. An Arduino microcontroller processes all sensor data, while the ESP32 module provides notifications in real-time on the mobile device of the homeowner.

This means that through integrating multiple sensors with IoT,the payback is found in security and comfort, but also in reduced power wastage. Now homeowners can receive, within seconds, real-time alerts, automated actions, or remote monitoring, all of which reduce response time in case of emergencies or prevent much worse energy wastage or disaster by keeping the living environment safer

II. LITERATURE SURVEY

Nowadays, home security cannot be considered a luxury it is a must. Traditional systems are mostly based on human onitoring that is why they often are too slow to prevent a break-in. Due to this fact, researchers nowadays tend to shift towards IoT-based smart home security systems. Such a system can respond automatically without the need for continuous human supervision and acts much quicker than any other conventional system. A large amount of research has been done on intrusion detection, smart sensors, and IoT monitoring. The major findings of the related studies are reviewed in this section.

Awad and Hamed [1] conducted a review of intrusion detection methods in the IoT environment. The authors emphasize that most IoT devices usually do not have strong built-in security; therefore, such devices are easy targets. The authors give an overview of various attack detection techniques for smart homes, indicating a need for lightweight and

efficient solutions suitable for everyday IoT devices. Nguyen et al. present [2] an anomaly detection system that learns what is considered “normal” for IoT devices and flags anything unusual. This work illustrates how machine learning can be used to enhance home security with very little human involvement.

Roux et al. presented [3] a solution that performs intrusion detection based on radio signal analysis rather than relying on specific network protocols. Because it is independent of protocol types, RadIoT is applicable to almost all IoT devices. A team led by Hızal [4] designed an IoT-based smart home security system incorporating machine learning. Their design deploys sensors to detect unusual events, while various AI techniques are used to improve accuracy. Bisht et al. [5] have proposed an intrusion detection system driven by AI, which can handle sensor data in much shorter time and with minimal errors compared to manual systems. Their findings express the intense role of AI in bolstering up security at homes.

Ingole [6] deployed sensors, such as a motion detector, smoke alarm, and a gas sensor in an IoT environment. Their system’s main advantage is being able to send real-time alerts to the homeowner for immediate action in case of any emergency.

Arinde and Idowu [7] have proposed a multi-sensor intrusion detection system wherein data from several sensors is combined together to reduce false alarms and ensure more reliable threat detection.

Patrer et al. [8] discussed the future trends in smart home security through IoT integration. The modern ’smart’ home integrates modern surveillance, automation, and remote access, and greatly enhances home control and convenience. Even prior to the wide popularity of IoT, Hu and Zhou [9] had designed a wireless sensor network for home security. Their work showed that already at that time, wireless networks were effective in detecting intrusions and environmental hazards.

Later, in 2018 [10], a study was published by that presented a hybrid sensor network, mixing wired and wireless connections, which provides strong coverage with improved reliability of intrusion detection.

Authors	Method	Algorithm / Approach
Awad & Hamed [1]	IoT Intrusion Detection Review	IoT Attack Detection Methods Survey
Nguyen et al. [2]	IoT Anomaly Detection	ML-based behavioral modeling of devi activity ce
Roux et al. [3]	RF-based Intrusion Detection, called RadIoT	Protocol-independent RF signal analysis
Hızal et al. [4]	Smart Home Security System	Multi-Sensor Machine Learning Analytics
Bisht et al. [5]	AI-driven Intrusion Detection	Sensor data processing using AI
Ingole [6]	Sensor-based Home Safety System	Integration of motion, smoke and gas sensors, real-time detection and alerting
Arinde & Idowu [7]	Multisensor Intrusion Detection	Sensor fusion
Patrer et al. [8]	Future Trends of IoT Smart Home	Smart automation and security technologies
Hu & Zhou [9]	Wireless Sensor Net- work Security	Intrusion detection us- ing WSN
2018 Study [10]	Hybrid Sensor Net- work	Combination of wired and wireless sensors

Performance	Advantages	Applications
Identification of IoT vulnerabilities	Need for lightweight, efficient solutions	Smart intrusion detection home
Detects abnormal behavior	Low human involvement	Smart moni- home toring
Works across the variation of IoT devices	No dependency on the types of network proto- cols	Generic intru- IoT sion detection
High accur acy detection	Rapid response & im- proved detecting precision	Smart intru- home sion detection
More speedy de- tection with fewer errors	Minimum manual effort involved, high through- put	Home intrusion detection

Immediate notification to the homeowner	Detection of emergency and hazard	Emergency and haz-ard detection
Fewer false alarms	Improved detection reli-ability	Home security mon-Itoring
Better automation	Greater convenien-ce and remote control	Smart home automa-Tion
Effective early detection	Feasible wireless pro-tection	Intrusion and hazard Detection
Strong and stable coverage	Reliable intrusion detection	Home intrusio-n Monitoring

III. OBJECTIVES

The main objectives of this project are:

1) Designing a cheap and efficacious security system, first through sensors and controllers that people normally find.
2) Sensing a visitor and sending intimation to the user about it using IoT for communication.
3) Opening a door lock by a servo motor from a remote position.
4) Indoor monitoring of gases potentially harmful or smoke based on detection, followed by an immediate alert.
5) Automating indoor light based on peoples' movement as well as natural light to save on electricity.
6) Multiple layering of security using various sensors for enhanced reliability.
7) To build a well installable, maintainable, and expandable system in the future.

IV. COMPONENTS USED

Component	Specification	Function
Arduino Uno	16 MHz clock, 14 digital I/O pins, 6 analog pins	Smart intrusion de-tection home
ESP32	Wi-Fi and Bluetooth enabled, 240 MHz	Handles IoT communication and sends mobile notifications re motely.
Ultrasonic Sensor (HC-SR04)	Measures distance 2– 400 cm, 5V suppl	Detects visitors approaching the door.
PIR Motion Sensor	110° detection angle, 3–7 m rang	Detects motion inside the home
MQ2 Gas Sensor	Detects LPG, methane, propane, smoke	Monitors gas leaks and triggers alerts.
Servo Motor (SG90)	0–180° rotation, 1.8 kg·cm torque	Controls door locking/unlocking remotely.
Laser Diode	650 nm wavelength, 3–5V	Forms a tripwire for intrusion detection with LDR.
LDR	10 k–1 M	Detects interruptions in the laser beam and ambient light levels.
LED	2V, 20 mA	Provides automated lighting.
Buzzer	3–5V, 85 dB	Gives audible alarms.

V. SYSTEM DESIGN AND WORKING

The proposed smart home security system is designed to provide multiple layers of protection and automation for enhanced safety and convenience. The system combines several sensors, actuators, and IoT technology to monitor the home environment in real time and respond appropriately to different conditions.

A. Door Security with Ultrasonic Sensor

Upon the approach of any entity within a specified range, generally around 50 centimeters, the sensor sends a trigger signal to the Arduino microcontroller, whereupon the ESP32 transmits the information of an intruder to the homeowner's mobile device, and an instant notification is sent to the device. Upon authentication, a command is sent to the servo motor for unlocking the door, allowing safe and secure access to the homeowner using the mobile phone keypad without the use of physical keys.

B. Gas and Smoke Detection

The fire and gas leak hazard is taken care of by the MQ2 gas sensor. This sensor regularly checks the air quality for the presence of harmful gases like LPG,

methane, and smoke. The moment the concentration of gas goes above a certain limit, an alarm is set off and alerts are sent to the user's mobile device in real-time. This alert equips the user, giving them a chance to avert accidents and ensure their home remains secure.

C. Motion and Light Automation

The idea behind the working of this system is to makelighting smart and energy-efficient. It involves using a PIR motion sensor that is able to sense any person moving inside a room. When an individual enters the room or walks around, the PIR sensor detects this movement and instantly turns the LED light on. If the person leaves the room or if no movement has occurred for some period of time, the sensor interprets it as an empty room. After this time of no motion, the system automatically turns the light off. In this case, the light will only be on when really needed; you are saved from remembering to turn off the lights, and electricity does not go to waste when the room is empty. While the system provides ease to the user, it provides the added advantage of saving power.

D. Laser & LDR for Intruder Detection

The laser beam aimed at the LDR sensor adds another layer of security forming an invisible tripwire. A beam interruption by any element like an intruder crossing through will alert the homeowner by sending a message to his mobile device. Hence the system guarantees reliable detection even when other sensors might have failed or are not directly activated by motion at the main entrance .

E. IoT Communication and Integration

The system is provided with internet connectivity via the ESP32 microcontroller for real-time communication with mobile devices. The user can monitor the home from anywhere and receive notifications and relay commands to actuators like a servo motor for remote unlocking. Thus, the integration of the IoT means that the system will always be open for access and be reactive even with the user out of the home.

F. Overall System Operation

Figure 1 Show All sensors communicate to the Arduino microcontroller; here, the information gets processed and then acted upon. On commands from Arduino, the actuators i.e. LED lights, buzzer, and servo motor position themselves. The ESP32 handles all communications with the cloud and mobile devices for remote monitoring and control. The amalgamation of all these constituents gives a complete solution for smart- home automation and real-time security.

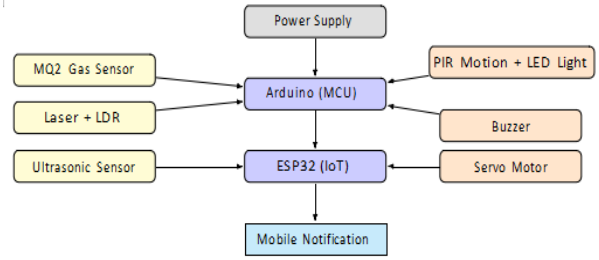

Figure 1: Block Diagram of Smart Home Security System

VI. RESULT AND ANALYSIS

The smart home security system was rigorously tested in real-life situations to check for any performance, reliability, and responsiveness it might have under such conditions. Each component was assessed independently and within the integrated system to ensure coordinated operation. The goal of the ultrasonic sensor located at the entrance is to detect an approaching person entering a corridor at a distance ranging from 40 to 60 cm from the door. On detecting a person, the system sends an instant alert notification to the homeowner's mobile device, wherein the servomotor attached to the door operates immediately upon receiving the control commands. This shows that the feature works quite fast and is accurate, except for the few times when small moving objects like pets generated false alerts.

The monitoring indoors for the presence of smoke, LPG, methane, and propane with the help of an MQ2 gas sensor was carried out. This gas sensor worked excellently during the test, detecting small amounts of either smoke or gas, activating the buzzer, and notifying the mobile phone. The response time was recorded to be three to five seconds, which is fairly okay in averting hazards such as fire or gas leakage accidents. This ability speaks for early warning and safety monitoring of the system.

The motion detection and lighting automation system, which comprised a PIR sensor and LDR, worked well in various lighting conditions. LED lighting was switched on automatically upon the entry of a person into a dark room, giving convenience and saving energy. No light was put on while the room was either unoccupied or

already well illuminated. This illustrates how energy efficient the system is while ensuring the comfort of the users.

Laser and LDR techniques for intruder detection helped to give extra security. The breaking of the laser beam was an immediate trigger for sending an alert to the homeowner's mobile phone. This proved to be fairly reliable and can act as a backup to both the ultrasonic and motion detection systems for extra assurance.

The ESP32 microcontroller would, by far, support and maintain communication for IoT throughout the testing. There were no observable delays in mobile notifications, which permitted instant monitoring and control. The servo motor controlling the door worked seamlessly, locking and unlocking command within one to two seconds, representing reliability and real-life applications in the system.

In summary, the smart home security system was successful in integrating multiple sensors for complete safety and automation. It exhibited fast response time, reliable detection of intruders and environmental threats, and efficient energy management. Minor drawbacks such as the rare false alert from the ultrasonic sensor and some little fluctuation of Wi- Fi connectivity were observed, but none greatly affected the overall operation. The system proves effective, practical, and scalable in real-world home security applications.

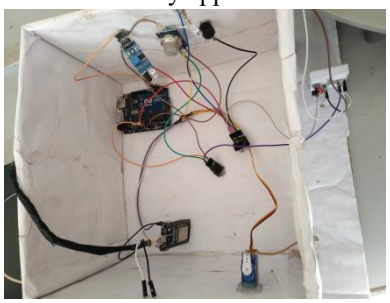

Fig. 2. Implementation of the multi-sensor security setup.

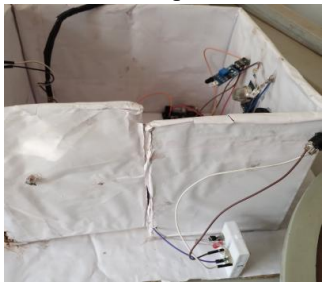

Fig. 3. Implementation of the IoT control and alert system.

VII. ADVANTAGES

- Real-Time Alerts: This will instantly notify the home- owner on a mobile device for a quick intruder response, gas leak alert, and fire warning.
- Remote Control: Doors can be locked or unlocked re- motely, which is useful for convenience and security.
- Early Hazard Detection: The MQ2 gas sensor and smoke detection serve the purpose of preventing accidents by early warning to the user in dangerous conditions.
- Energy Efficiency: Automatic lighting controlled by PIR and LDR sensors eliminates wasteful power consumption and conserves energy.
- Cost-Effective: The system employs easy-to-find and cheap components that render it far more suitable for extensive use.
- Increased Security: The combination of various sensors will provide a more trustworthy and robust security system than conventional single-sensor systems.
- Scalable and Flexible: The system can easily integrate additional sensors or features after deployment as the security needs change.

VIII. CONCLUSION AND FUTURE SCOPE

Provides an efficient and effective demonstration for conveying how multiple sensors, combined with IoT technology, can enhance safety, convenience, and energy efficiency in a home environment. An ultrasonic sensor, PIR motion sensor, MQ2 gas sensor, laser-LDR setup, and automated lighting are all integrated into a layered and reliable security system that is easily practical. It comes with mobile notifications in real time and door control from anywhere via an ESP32 micro- controller, offering a homeowner the capability to monitor and control their household from anywhere, bringing about huge convenience and peace of mind.

Testing indicates an instant response to intrusions, gas leakage, and changes in the environment, while automated lighting improves the energy efficiency of the system, all with- out compromising comfort. Minor setbacks include misfiring catch-all alerts came across few times as well as sensitivity to ambient light, which can be improved on in the near future. In reality, this system features a cost-effective,

scalable, and futuristic, having put the advantages of IoT-based smart home security solutions to test suitability in both modern residential and office applications.

Some of the probable future extensions of the intelligent home security system for further advancement, better efficiency, and enhanced user-friendliness are as follows:

- Integration of Cameras: Such function could enable real- time live viewing with cameras that allow the homeowner to verify alerts and record events for security purposes.
- The dedicated Mobile Application: would not only allow full control over the system with monitoring and notification and actuator management but via a user-friendly interface.
- Voice Control: Since it can be configured with Google Assistant or Amazon Alexa, voice-based operation can also be incorporated into household systems to allow hands-free operation.
- Advanced Modes of Notification: The adoption of SMS, WhatsApp, or email alerts can provide all-important notifications even without being logged into the mobile application.
- Solar Powered: These are not only the renewable energy sources because of solar panels and eco-friendly electricity generation but also reduce dependency on commonly used electricity.
- Interconnected with the Smart Home Eco-System: The system should be fit to interlink with other smart devices in a home ecosystem such as a smart thermostat, appliances, and energy management systems for a complete smart home experience.
- Advanced Analytics: High-end forecasting of unusual activity, especially in regard to threats, is possible through data analytics and machine learning technique.

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