SmartSentinel : IoT Based Smart Home Safety

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***Abstract*— Residential safety remains a critical concern as traditional security measures often lack real-time responsiveness and integrated hazard detection. This study aims to develop an automated smart home ecosystem that addresses three primary household risks: unauthorized access, suspicious activity monitoring, and environmental hazards like gas leaks.By combining computer vision with hardware-level fail-safes, this project provides a multifaceted approach to domestic protection. These findings suggest that integrating modular sensing units into a unified response system significantly enhances user safety and mitigates the impact of both human-led and environmental household threats.**

***Keywords*— Smart Door Lock, ESP32 Camera module, C++, Gas Leak Detection, Home Security, IoT, Automation**

I. INTRODUCTION

As a central pillar of the Internet of Things (IoT), smart homes have redefined how we interact with our living environments by enabling seamless communication between various digital devices. In an ideal "wired future," every component within a household works in unison to provide connectivity and convenience regardless of time or location. These systems have evolved from simple automation into sophisticated infrastructures capable of exchanging complex data from sensors and software modules to manage daily life. By networking physical devices—from lighting to advanced environmental sensors—a smart home creates a domain where security and comfort are managed remotely via the internet.[1]



Fig. 1 Integrated smart home security system with remote access control.

However, as the number of internet-connected devices in our homes increases, so do the concerns regarding privacy and physical security. While users appreciate the ability to monitor data like heat, light, and humidity, traditional surveillance equipment like cameras and microphones can often feel like a double-edged sword; if not properly secured, they risk being exploited by intruders to monitor a resident's private life. Furthermore, many current systems remain passive observers rather than active defenders. For example, while a standard system might detect smoke or gas, it often lacks the automated response necessary to physically mitigate the threat, such as cutting off a supply valve or improving ventilation.

To bridge this gap, this project proposes an integrated IoT safety ecosystem that prioritizes active response over passive monitoring. By utilizing the modular nature of IoT, we have developed a system that manages three critical safety areas: secure access, intelligent surveillance, and environmental hazard mitigation. Our approach

involves a Smart Door Lock with dynamic authentication, an unauthorized entry detection module with an ultrasonic sensor and ESP32 camera module that detects trespasser, clicks his snapshots and plays buzzer to alert the neighbourhood, and a Gas Leak Detection system that automatically triggers mechanical fail-safes. By focusing on these specific daily conveniences and security needs, this research aims to provide a more robust and trustworthy framework for modern smart home protection

II. METHODOLOGY

A. Proposed System Architecture

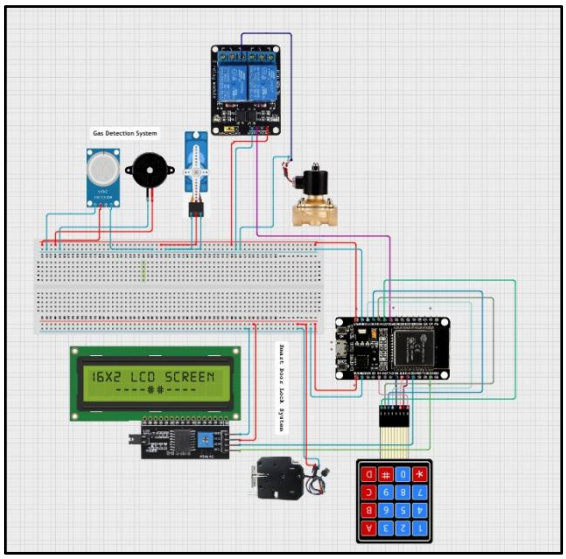


Fig. 2 Illustrates the hardware architecture of the smart home safety system.

The core of this project is built on an integrated framework that moves away from passive monitoring toward a system capable of real-time intervention. By centralizing the control logic within an ESP32 based architecture, we created a localized network that handles security, surveillance, and environmental safety through three distinct logic flows.

1) Access Control and the Smart Door Lock

Instead of relying on a single physical key or a static code that can be easily stolen, we implemented a multi-stage authentication process. For daily use, the resident logs into a web interface to generate a "run-time" password, which is then entered on a physical I2C-connected keypad to retract the solenoid lock.

2) Vision-Based Monitoring (CCTV)

The Trespasser Detection Module serves as the primary internal security layer of the SmartSentinel system, utilizing a precision-based approach to identify and document unauthorized access. Unlike traditional PIR-based motion sensors that are prone to thermal noise, this module employs an ultrasonic sensor to establish a stable, distance-mapped detection boundary. When an object enters the predefined proximity threshold, the ESP32 camera which is displaying live feed of the house to the user simultaneously captures high-resolution snapshots of the intruder. To ensure data integrity and forensic accountability, these images are instantly transmitted and stored in a Supabase cloud database via REST API. This cloud-centric architecture ensures that even if the physical hardware is tampered with or destroyed during a breach, the user retains a permanent, tamper-proof record of the event accessible from any location.

3) Automated Gas Mitigation Circuit

The most critical part of the system is the gas leak response, which we designed to act even if the residents are asleep or away. Using an MQ-2 gas sensor, the microcontroller continuously polls the air for hazardous concentrations.

Once the sensor data crosses a pre-set safety threshold, the system executes two physical safety protocols:
Ventilation: A servo motor is used to mechanically open a window or toggle an exhaust fan to clear the air.
Containment: A relay module cuts power to the solenoid valve, which effectively shuts off the gas supply line to prevent a potential explosion. Throughout this process, a buzzer sounds a local alarm to notify occupants of the danger.

B. Components Used

1) Core Controller and Interface

a) **ESP32 Microcontroller:** Serves as the primary controller for processing sensor data and managing connectivity.

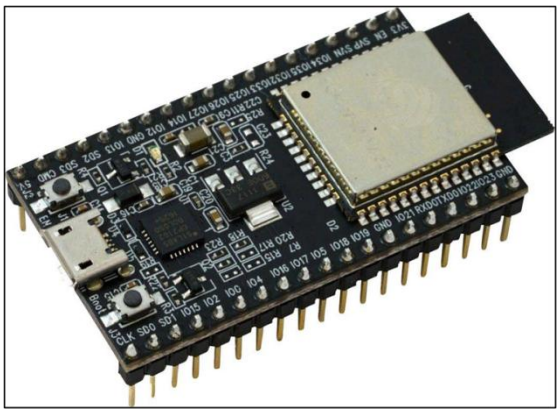


Fig. 3 ESP32 Microcontroller

ESP32 is a family of low-cost, energy-efficient microcontrollers that integrate both Wi-Fi and Bluetooth capabilities.[3]. The heart of our setup is the ESP32, chosen specifically because its dual-core architecture allows it to multitask between hosting an authentication site and processing live sensor inputs. Its versatile GPIO pins and support for I2C and PWM protocols provide the precise control needed to synchronize the solenoid locks, servo-driven ventilation, and the ESP32 Camera module for intruder detection.

b) **16x2 LCD Screen with I2C Module**:Used for displaying system status and password prompts.

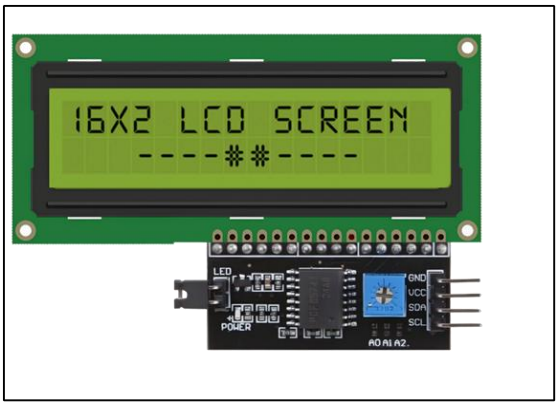


Fig. 4 16x2 LCD Screen with I2C Module

Figure 4 illustrates the 16×2 LCD screen with an I2C module which is used to display real-time system messages such as password prompts, authentication status, gas leak alerts, and system notifications.The I2C module reduces wiring and saves ESP32 pins, allowing easy communication between the microcontroller and the LCD while keeping the circuit simple and efficient.

c) **4x3 Matrix Keypad:** Provides physical input for the manual door lock override and run-time password entry.



Fig. 5 4x3 Matrix Keypad

The 4x4 matrix keypad module is an essential component in many electronics projects as it offers a convenient and efficient way to input data. It is used in our project to type in the password after it is generated runtime on the website to unlock the door.

d) **Breadboard and Jumper Wires:** Used for prototyping the circuit connections between the controller and modules.

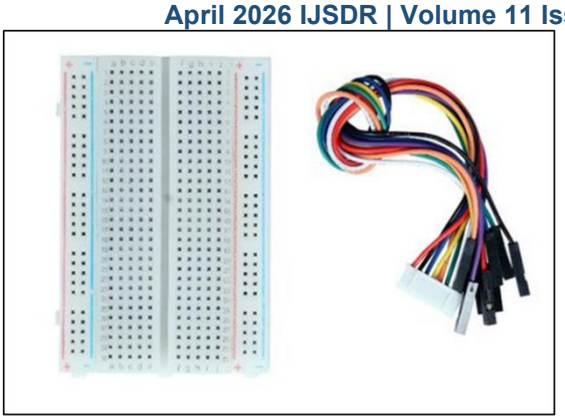


Fig. 6 Breadboard and Jumper Wires

A breadboard is a solderless construction base used to build, test, and prototype electronic circuits without needing to solder components and A jumper wire (or jumper) is an electrical wire or cable with connector pins at each end, designed for prototyping and testing circuits by connecting components on a breadboard or PCB without soldering.

2) Safety and Mitigation Module

a) **MQ-Series Gas Sensor**: · Specifically used to detect hazardous gas concentrations (LPG/Natural Gas).

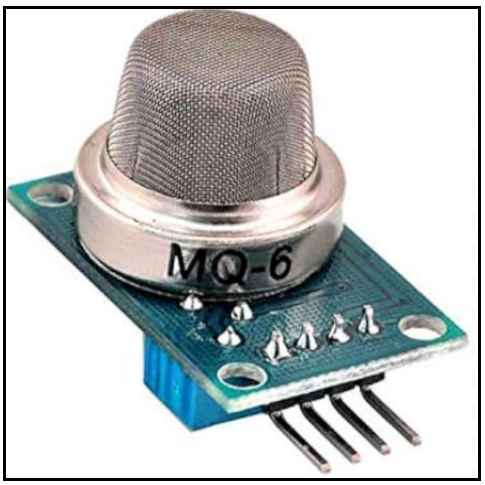


Fig. 7 MQ6 Gas Sensor

The electronic gadget called the MQ6 gas sensor is capable of detecting a wide range of gases, including hydrogen (H2), propane, liquefied petroleum gas (LPG), methane (CH4), carbon monoxide (CO), alcohol, smoke, and others. It is commonly used in household and industrial settings to identify gas leaks and avert potential hazards. One of the most remarkable characteristics of the MQ6 gas sensor is its high sensitivity and quick reaction time, which enable early detection of gas leaks. This expertise is essential since gas leaks may risk human life and safety, damage equipment, and contaminate the environment. To adjust the sensor's sensitivity, this is equipped with a potentiometer, which is a variable resistor that allows the user to adjust the reference voltage of the circuit board. This makes it possible to optimize the sensor's performance and detect gases at specific concentrations.[4]

b) **2-Channel Relay Module:** Acts as an electronically controlled switch to manage power for the solenoid valve.

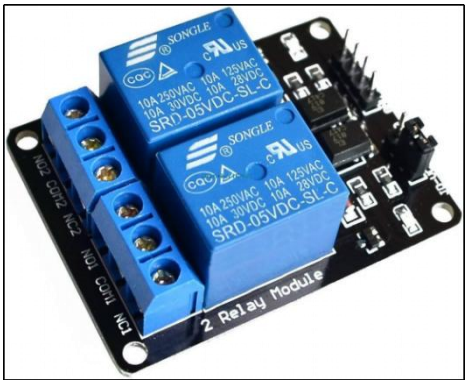


Fig. 8 2-Channel Relay Module

A 2-channel relay module is a device that allows you to control two independent circuits using a single module. Each channel contains a relay that can switch a high-power circuit on or off. When a microcontroller sends a low or high signal to the input pins (IN1 or IN2) of the relay module, it activates the corresponding relay. The relay module interprets this signal to control the switching of a connected high-power device.

Solenoid Valve (12V): Physically shuts off the gas supply line when a leak is detected.



A solenoid valve is an electromechanically operated valve used in pipelines to regulate the flow of liquids or gases. It is used in the SmartSentinel system to shut off gas supply when a gas leak is detected.

c) **Servo Motor:** Activates an exhaust fan for ventilation when gas leak is detected.



A servo motor (servomotor) is a highly specialized motor designed for precise control of rotary or linear motion. It's a rotational or translational motor that employs a feedback mechanism to ensure exact positioning, typically using a control signal that dictates the motor's movement to a desired position. To provide active ventilation, a high-torque servo motor is mechanically linked to a window or air vent.

Piezo Buzzer: Sounds a local audible alarm during gas leaks or unauthorized entry attempts.



A piezo buzzer is a type of electronic device that's used to produce a tone, alarm or sound. It is lightweight with a simple construction, and it is typically a low-cost product.

3)Surveillance and Access Hardware

a) **ESP32 Camera:** The ESP32-CAM is a compact, Wi-Fi-enabled development board that serves as a standalone web server capable of streaming live MJPEG video to a browser and capturing high-resolution JPEG photos directly to an onboard microSD card or remote server.



Fig. 12 ESP32 Camera

b)**Electronic Door Strike/Solenoid Lock**: The physical locking mechanism controlled by the ESP32.



Fig. 13 Solenoid Lock

The Solenoid Lock serves as the physical enforcer of the security logic, converting digital authorization into mechanical action. This component replaces traditional, static keys with a dynamic system where the bolt only retracts once the ESP32 verifies a correct run-time password from the web interface.

c) **12V Power Adapter:** Provides the necessary external power for high-current components like solenoid valves and relays.



Fig. 14 12V Power Adapter

d) Ultrasonic sensor: Ultrasonic sensors use high-frequency sound waves (ultrasound) to measure distance, detect objects, or monitor levels without contact. They are highly versatile, independent of light, smoke, or material color, making them ideal for industrial automation, robotics, liquid level sensing, collision avoidance, and parking sensors.



Fig. 15 Ultrasonic Sensor

C. Working

This IoT-based project integrates three core modules: a smart door lock, an intrusion detection system, and a gas leak detection system. A key feature is the automatic generation of unique passwords every 30 seconds or whenever the door is operated. The system utilizes the ESP32 Camera to show live feed of internals of the house, ultrasonic sensor detects presence of intruder when user is away from home and ESP32 clicks intruder's snapshots and saves it to supabase cloud, triggering a local alarm upon detecting unauthorized individuals. In the event of a gas leak, the system reaches a pre-set threshold to activate a servo motor for ventilation, shut off the gas supply via a solenoid valve, and automatically unlock the door.

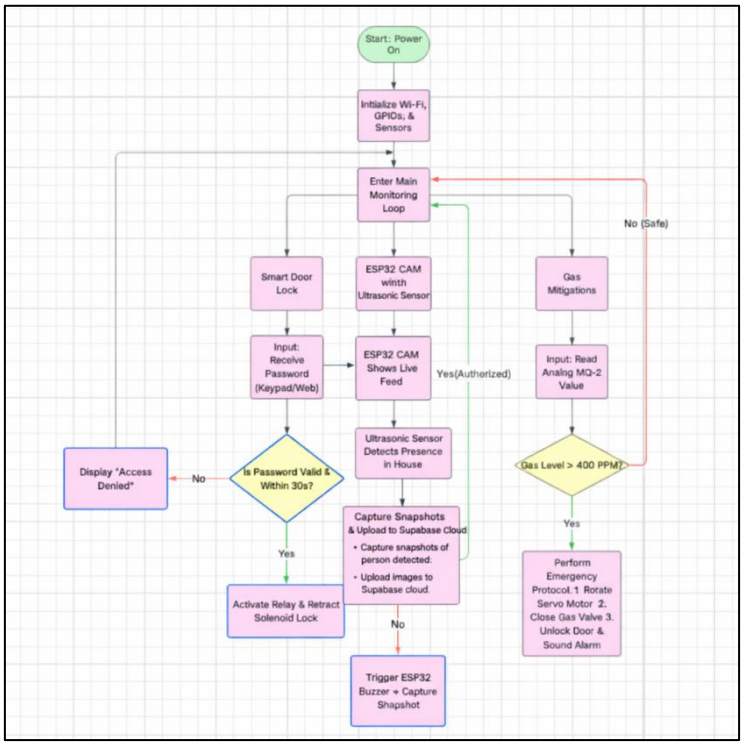


Fig. 18 SmartSentinel System Workflow

While the flowchart outlines the internal decision-making logic of SmartSentinel, the following Sequence Diagram illustrates the temporal communication between system components. It provides a detailed view of how the User, Web Interface, ESP32, sensors, and physical Actuators interact and exchange messages to execute security protocols in real-time.

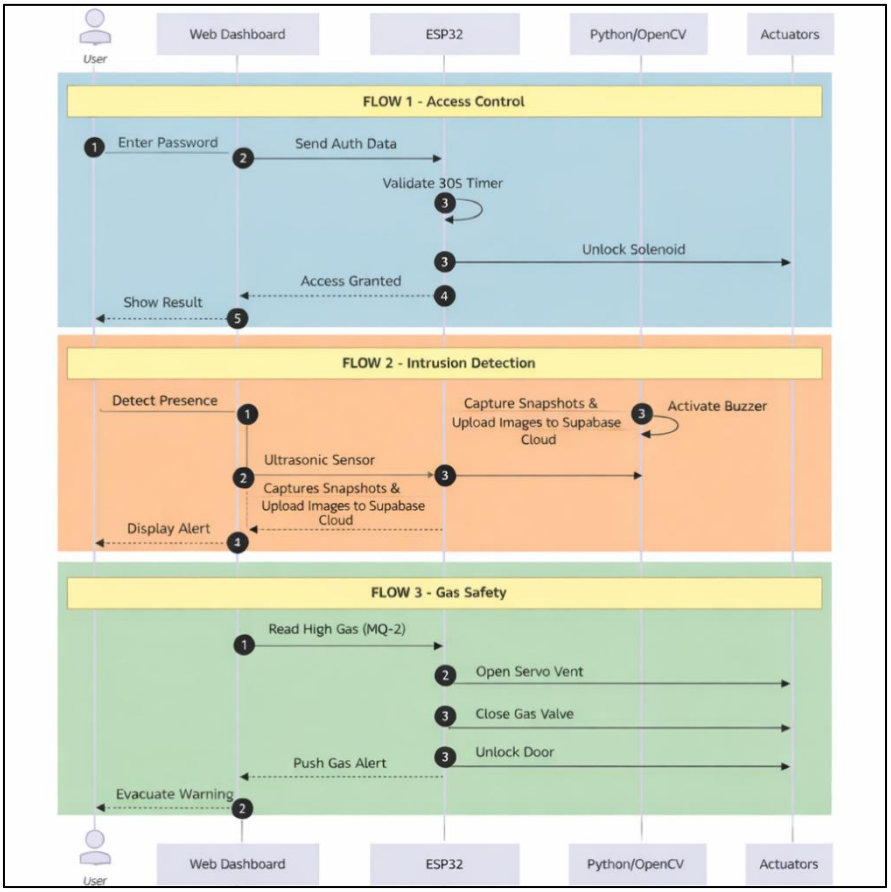


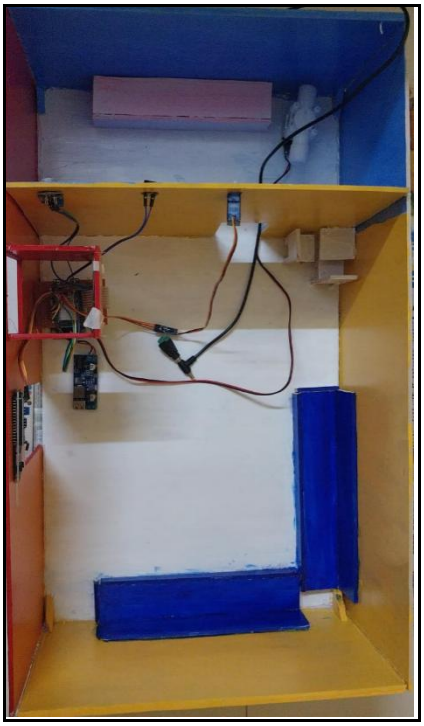
Fig. 19 Sequence Diagram of the SmartSentinel Communication Flow.

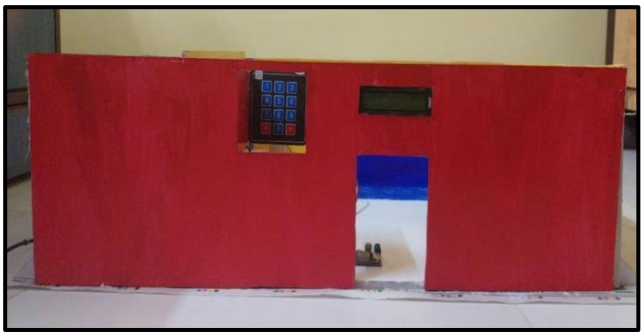
Authentication Phase: This phase verifies if the runtime password to unlock the door on the web dashboard matches the password entered by the user on the I2C keypad. If both passwords match, only then the status of the smart door lock changes to unlocked and is displayed on the lcd screen as well as the web dashboard.

Detection Phase: This module implements an ESP32 Camera, an ultrasonic sensor and Supabase cloud. The ESP32 Camera shows the live feed of the interior of the house to the user on the website when the user is away from home. When a tresspasser enters the house, the ultrasonic sensor detects its presence and the ESP32 Camera clicks intruder's snapshots and saves it to the Supabase cloud and a buzzer plays to alert neighbourhood.

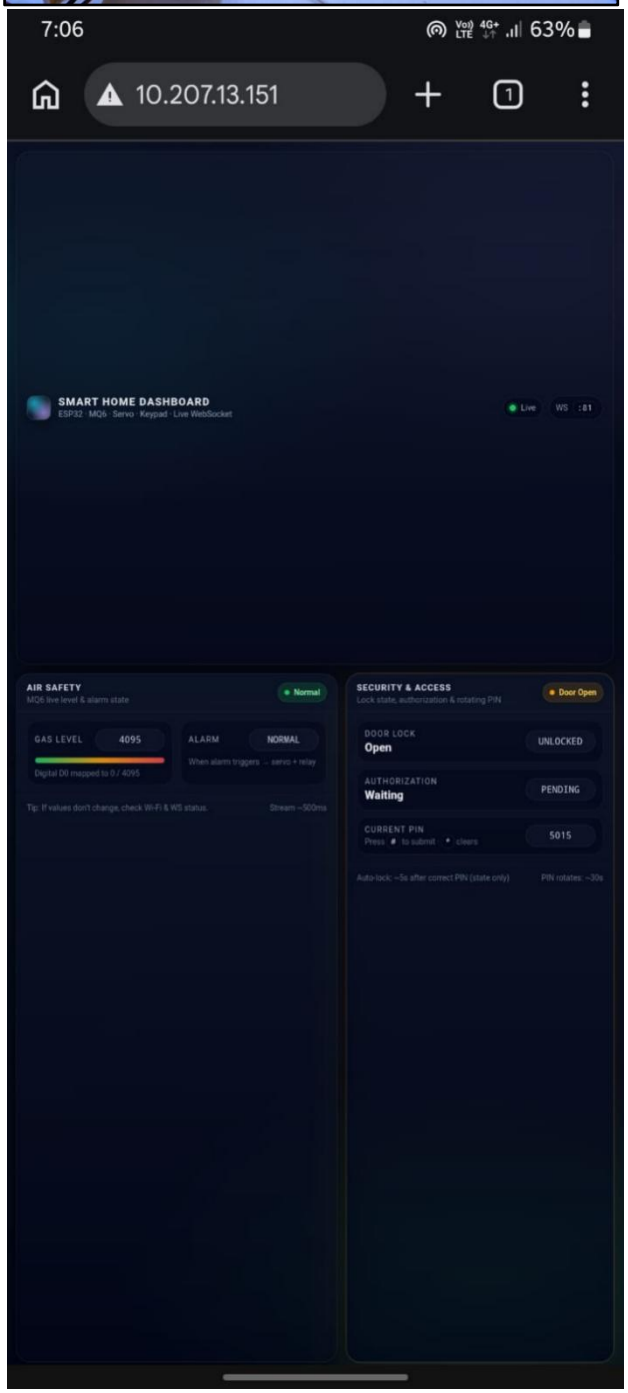
Mitigation Phase: It describes the autonomous safety response to a gas leak. "Mitigation" means reducing the severity of a dangerous situation.As soon as the MQ-2 sensor detects gas levels above the safety limit, the ESP32 immediately switches on the relay to cut off the gas solenoid valve and moves the servo motor which plays role of an exhaust fan.This module proves that whether or not human is not present in the situation it will automatically do its job and prevent a threatening situation from occurring.

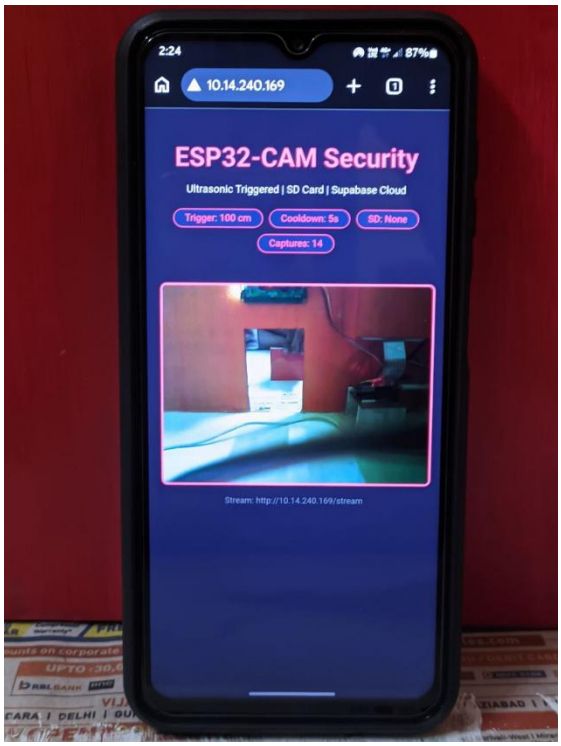
D. Result











Observations:

System Componet / Action	Trigger Event	Measured Response Time	Functional Status
MQ-6 Gas Sensor	Gas Concentration > Threshold	1.0 s	Detection Active
Solenoid Valve	Critical Gas Leak Detection Signal	1.0 s	Solenoid valve (gas supply) shut off successfully
Servo Motor	Critical Gas Leak Detection Signal	1.0 – 2.0 s	Ventilation Active

Emergency Door Release	Critical Gas Leak Detection Signal	1.0 s	Door unlocked
Smart Lock Access	Valid Password Entry	1.0 s	Entry Granted
Password Expiration	Door Lock Engagement	Immediate	Security Reset
Password Expiration	Idle Timeout	30.0 s	Auto-Invalidation

E. Discussion

During the integrated testing of SmartSentinel, the system demonstrated a dual-layered defense strategy. For Internal Security, the ultrasonic sensor acted as a precise proximity trigger, the ESP32 which is responsible for showing live stream of house to the user successfully captured trespasser snapshots to the Supabase cloud within seconds. Simultaneously, the MQ-6 gas sensor maintained continuous environmental monitoring. It was observed that upon detecting a breach of safety thresholds (simulated gas leaks), the system shut off the solenoid valve, effectively isolating the hazard without human intervention.

SmartSentinel stands out than other available products in the market because most market solutions are "siloed" that means individual modules working independently. SmartSentinel stands out by unifying these into a single proactive ecosystem:

- Hybrid Defense: It is one of the few low-cost prototypes that manages both forensic security and mechanical safety.
- Cloud-First Persistence: While standard systems rely on local SD cards that can be stolen or destroyed, our integration with Supabase ensures that all security logs are off-site and tamper-proof the moment they are captured.
- Proactive vs. Reactive: Most systems are only "reactive" but SmartSentinel is proactive for e.g. it doesn't just tell you there is a leak; it stops the leak.

Key Advantages of the Full System

- Holistic Household Protection: By covering both unauthorized access and environmental hazards, the system provides a 360-degree safety net for the user.
- Forensic Accountability: The automated cloud-upload feature provides high-resolution evidence that remains accessible globally, even if the physical hardware is compromised during a break-in.
- Autonomous Reliability: The system's ability to act independently using distance-mapping for intruders and threshold-triggering for gas ensures protection 24/7, even if the user is asleep or away.
- Scalable & Cost-Effective: By leveraging the ESP32 and open-source cloud backends, the project delivers professional-grade "Smart Home" features on a student-friendly budget.

F. Conclusion

The SmartSentinel project successfully demonstrates a cohesive IoT-based approach to residential security and hazard mitigation. By integrating real-time image processing with an automated gas leak response system, the project addresses both external threats and internal safety risks. Experimental results confirm that the system operates with high efficiency, with the MQ-6 sensor and solenoid valve responding within a critical 1-second window. The implementation of a password auto-reset mechanism significantly reduces the risk of credential theft, while the automated ventilation and emergency door release ensure occupant safety during environmental crises. Ultimately, SmartSentinel provides a scalable, reliable, and cost-effective solution for modern smart home protection.

G. Acknowledgments

We would like to express our deep sense of gratitude to Mr. Manish Salvi for their expert guidance and suggestions throughout the development of this IoT Based Smart Home Safety system - SmartSentinel. We are also sincerely thankful to Ms. Vaishali Rane, Head of Computer Engineering Department, for providing the facilities and academic support necessary to bring this research to fruition.Furthermore, we extend our appreciation to the open-source community, particularly the contributors to the ESP32 ecosystems, whose invaluable resources and libraries formed the backbone of our software architecture.

We are also grateful to our teammates for their collaborative spirit and shared dedication in overcoming the technical challenges of this project. Finally, we owe a special thanks to our families for their constant encouragement and unwavering support during every stage of this work

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