2025 Jurnal Kejuruteraan, Teknologi dan Sains Sosial
Journal of Engineering, Technology and Social Science
Volume 11 Issue 1, e-ISSN: 27166848

HOME SECURITY MOTION SENSOR WITH SPYCAM USING TELEGRAM

Mohammad Mursyeed Ramli[1] and Muhamad Zaki Abdul Rahman[2]

[1,2]*Jabatan Kejuruteraan Elektrik, PUO, Malaysia*
[1]*m.muryeed@puo.edu.my*
[2]*zakiman@puo.edu.my*

ARTICLE INFO

Article history:
Received
24 March 2025
Received in revised form
11 May 2025
Accepted
14 May 2025
Published online
01 June 2025

Keywords:
Home security; Internet of Things (IoT); Surveillance system

ABSTRACT

Home security is becoming an increasing concern, and smart technology is now a more effective solution for real-time monitoring and instant alerts. This study proposes a home security system that integrates Passive Infrared (PIR) motion sensors and spy cameras with Telegram notifications to enhance response time and situational awareness. The system uses an ESP32 microcontroller to process sensor data and activate cameras when motion is detected. Real-time alerts are sent directly to homeowners via Telegram, allowing immediate action. Testing was conducted under various conditions, including different lighting and network strengths. Results showed a 90% accuracy in motion detection under optimal conditions, with an average notification response time of 2.5 seconds. However, some limitations were identified, such as reduced night-time surveillance effectiveness and reliance on network stability. Future improvements include infrared cameras for better low-light detection and backup connectivity options to enhance reliability. This study demonstrates that an affordable and efficient IoT-based home security system can provide homeowners with improved monitoring, faster response times, and enhanced security.

1. Introduction

In today's digital era, home security has become a growing concern due to the increasing number of break-ins and thefts **[1]**. Traditional security systems, such as mechanical locks and alarms, primarily function as deterrents, often failing to provide real-time monitoring and immediate response **[1],[2]**. The main drawback of these systems is their passive nature, where alerts are triggered only after an incident has already occurred, limiting homeowners' ability to prevent security breaches proactively **[3]**.

With advancements in the Internet of Things (IoT), home security systems can now be enhanced through the integration of smart technologies **[4]**. The use of Passive Infrared (PIR) motion sensors and surveillance cameras connected to communication platforms like Telegram offers a new level of security monitoring **[5]**. PIR sensors detect changes in infrared radiation caused by movement, allowing for automated surveillance activation when motion is detected

[5],[6]. By integrating these sensors with cameras, security systems can instantly capture images or record videos, significantly improving real-time monitoring [5],**[7]**.

Moreover, Telegram provides an efficient platform for sending instant notifications, ensuring that homeowners are immediately informed of any suspicious activity **[5]**. This real-time interaction enables quick decision-making, such as contacting authorities or assessing threats remotely **[5]**. By leveraging these technologies, home security systems can transition from being merely reactive to proactive, offering enhanced protection and reducing the risk of theft or property damage [5],**[7]**.

Problem Statement

Despite technological advancements in home security, many households still face significant challenges in effectively monitoring and protecting their properties **[8],[9]**. Traditional security measures, such as alarms and mechanical locks, offer basic protection but lack the ability to provide immediate and actionable alerts during critical incidents **[10]**. This limitation reduces homeowners' ability to respond swiftly to potential threats **[10]**.

Additionally, many existing surveillance systems suffer from coverage limitations and lack seamless integration with modern communication technologies **[11]**. Blind spots in security coverage increase the risk of undetected intrusions, while systems relying on local storage for footage restrict real-time access and pose a risk of data loss if storage devices are damaged **[12]**. Furthermore, the complexity of installation and operation in many security solutions discourages homeowners from adopting advanced monitoring systems **[13]**. Difficult setup procedures and non-intuitive interfaces often lead to improper usage, reducing the effectiveness of security measures **[8]**.

To address these issues, there is a pressing need for an advanced home security solution that integrates PIR motion sensors and spy cameras with a real-time notification system via Telegram. The proposed system aims to provide:

- **Enhanced Surveillance Coverage** by strategically placing PIR sensors and cameras to eliminate blind spots **[14]**.
- **Immediate Detection and Response** through automated alerts sent directly to homeowners' mobile devices **[15]**.
- **Covert Monitoring Features** that prevent intruders from identifying and disabling security components **[1]**.
- **User-Friendly Setup and Operation** to ensure ease of use without requiring technical expertise [1].

By resolving these challenges, the proposed system will significantly enhance home security, providing homeowners with improved monitoring, faster response times, and greater peace of mind.

Objectives

The primary goal of this project is to develop an integrated home security system that utilizes PIR motion sensors and spy cameras while leveraging Telegram for real-time notifications. This system aims to offer a more efficient, accessible, and responsive security solution.

Firstly, to develop a robust security system by integrating PIR motion sensors for movement detection and spy cameras for real-time visual monitoring. The system will be designed to provide comprehensive coverage of critical areas within a property, ensuring enhanced security without leaving blind spots. Furthermore, software development will focus on seamless connectivity between hardware components and the Telegram API, ensuring instant notifications and remote access capabilities for homeowners.

Secondly, to enhance real-time surveillance and response by utilizing Telegram's instant messaging features. The system will automatically send alerts and video feeds directly to users' smartphones, enabling immediate awareness and quick action when security threats are detected. Homeowners will also have the ability to interact with the system remotely, such as activating or deactivating sensors, viewing live camera feeds, and receiving security status updates.

Lastly, to ensure ease of use and accessibility by designing a user-friendly system with intuitive controls. The system's interface will be developed to facilitate simple setup and management, eliminating technical barriers for users. Additionally, comprehensive documentation and guidance will be provided to ensure that homeowners can operate and maintain the security system effectively.

By achieving these objectives, the proposed system aims to deliver a next-generation home security solution that enhances safety, reliability, and user convenience.

Addressing Key Security Challenges

This solution is designed to overcome key challenges in home security by improving surveillance coverage, minimizing response time, ensuring discreet monitoring, and enhancing user accessibility. One of the primary concerns in traditional security systems is their limited field of view, which creates blind spots that intruders can exploit **[16]**. By strategically positioning PIR sensors and cameras, the proposed system maximizes coverage, ensuring comprehensive monitoring of all critical areas.

In addition to coverage limitations, delayed detection and response remain major security concerns **[14]**. Many conventional systems rely on local alarms or recorded footage, only notifying homeowners after an incident has occurred. The integration of real-time notifications through Telegram ensures that any detected motion triggers an immediate alert, allowing for a swift response and reducing potential damages [5].

Another crucial aspect is the lack of discreetness in existing security setups **[4]**. Visible surveillance equipment can alert intruders, allowing them to evade or disable security measures. By incorporating covert monitoring elements, the proposed system remains

inconspicuous, increasing its effectiveness in detecting unauthorized access. Moreover, the complexity of many security systems often discourages homeowners from adopting them. To address this, the proposed system is designed for easy installation and operation, making advanced security technology accessible to a wider audience [4].

By tackling these challenges, the proposed system offers a modern, efficient, and user-friendly home security solution. Homeowners will benefit from enhanced protection, greater control, and peace of mind, knowing their properties are monitored in real time with a reliable and discreet security system.

1.1 Literature Review

Introduction to Literature Review

A literature review is a crucial step in the system development process as it enables researchers to understand current advancements in the field of study. By reviewing previous research, researchers can identify the strengths and weaknesses of existing systems, challenges faced, and innovations introduced in the field of smart home security. A literature review also helps in identifying research gaps that can be addressed through this study [1].

The primary focus of this literature review is to examine the development of smart home security technology by analysing existing systems and the challenges faced by homeowners in ensuring the safety of their residences. Technologies such as Passive Infrared (PIR) motion sensors and surveillance cameras have been widely used in home security systems to detect intrusions [2], [3]. However, conventional systems that rely solely on local storage and alarm systems still have limitations in providing immediate notifications to homeowners [4].

Furthermore, advancements on the Internet of Things (IoT) have enabled the integration of security sensors with modern communication platforms like Telegram for real-time notifications [5], [6]. Previous studies have shown that the use of IoT in home security not only enhances monitoring effectiveness but also allows homeowners to respond more quickly to potential threats [7]. However, challenges still exist, such as limited camera coverage (blind spots), delayed response times to threats, and difficulties in installing and using smart security systems [8], [9].

Through this literature review, the proposed system will be developed by addressing the weaknesses of existing systems and leveraging modern technology to provide a more efficient, user-friendly, and effective home security solution that enables immediate response to security threats [10].

Previous Studies on Home Security Systems

Home security is a crucial aspect of modern life, and various methods have been introduced to protect residences from intrusions and external threats. Traditionally, home security systems have relied on conventional methods such as mechanical locks, reinforced doors, and basic alarm systems. While these measures provide fundamental protection, they are often passive

in nature, serving only as deterrents without the capability to provide real-time alerts or immediate homeowner response to ongoing threats [1].

A study by Chitnis et al. (2016) highlighted that traditional security systems rely on physical mechanisms and local alarms that are only activated after an intrusion occurs [1]. However, a major drawback of these systems is the lack of remote monitoring and automated response, which can cause delays in taking action during security incidents. Additionally, these systems lack the ability to store visual records of events, making them less effective for investigation or preventing repeat incidents [1].

Over the past decade, technological advancements have transformed home security systems into smart security systems. Modern systems now incorporate Internet of Things (IoT), Artificial Intelligence (AI), and network-based surveillance to enhance monitoring capabilities and response to security threats [10]. A study by Chong et al. (2023) compared traditional and smart security systems, showing that the integration of motion sensors such as Passive Infrared (PIR) and smart cameras has significantly improved home monitoring efficiency [10].

One of the primary advantages of smart security systems is their real-time monitoring capability and instant notifications to homeowners via communication platforms such as Telegram, email, and SMS [5]. Unlike conventional systems that only trigger alarms upon an intrusion, modern security systems can detect threats before they occur by utilizing smart sensors and data analysis algorithms [10].

Furthermore, smart home security systems allow homeowners to remotely control and monitor their homes using mobile devices. A study by Osman et al. (2022) found that the integration of PIR sensors, surveillance cameras, and Telegram significantly enhances security by enabling immediate alerts when suspicious movements are detected [5].

Despite the numerous advantages of smart security systems, several challenges remain, including high installation costs, privacy concerns, and the risk of cyber-attacks on IoT-based systems [8]. Therefore, research in this field continues to evolve, focusing on aspects such as cost-effective solutions, data security, and ease of use.

Overall, previous studies indicate that the transition from traditional security systems to smart security systems has led to significant improvements in monitoring, response time, and overall home protection effectiveness. This research supports the integration of modern technologies such as PIR sensors, surveillance cameras, and Telegram in home security systems to enhance security and provide efficient real-time monitoring.

PIR Motion Sensor Technology in Home Security

The Passive Infrared (PIR) sensor is a crucial component in home security systems due to its ability to detect motion based on changes in infrared radiation emitted by objects such as humans or animals [6]. PIR functions by detecting temperature differences between a moving object and its surrounding environment, allowing it to act as a trigger for security systems such as surveillance cameras or alarm systems [14].

Previous studies have demonstrated that PIR integration in home security systems enhances monitoring capabilities and threat detection efficiency. For example, a study by Kurniawan (2021) found that combining PIR sensors with IoT-based security systems enables automatic camera activation and instant notifications to homeowners via messaging applications such as Telegram [6]. However, PIR technology also has limitations, including sensitivity to non-human heat sources and difficulty detecting motion outside its coverage range.

Integration of Surveillance Cameras with Automated Systems

Surveillance cameras play a crucial role in enhancing home security by providing real-time visual monitoring. Modern surveillance systems now utilize smart cameras that can be connected to IoT networks for live video transmission and automatic threat analysis [5].

One of the primary concerns in using surveillance cameras is the choice between local storage and cloud storage. Local storage is commonly used in traditional security systems; however, it has limitations such as the risk of data loss due to device damage or theft of recording equipment [12]. On the other hand, cloud storage enables homeowners to access recordings from any location and ensures data security. However, it relies on a stable internet connection and may raise concerns regarding privacy and long-term subscription costs.

Use of Telegram as a Security Notification Platform

Telegram has become a popular platform in home security systems due to its capability to send instant notifications to homeowners when sensors detect suspicious movements [5]. Telegram's ability to support automated bots allows users to receive alerts in real-time, interact with the system to view recorded footage, or even control security devices remotely [7].

Compared to SMS, WhatsApp, or email, Telegram offers greater flexibility as it supports an open API and end-to-end encryption, enhancing communication security [7]. Additionally, Telegram does not require extra charges like SMS, making it a more cost-effective and user-friendly option for home security systems.

Challenges in Implementing Smart Home Security Systems

Although smart home security systems offer numerous advantages, several key challenges remain in their implementation. One major issue is blind spots in camera coverage, where home layout and furniture placement can obstruct movement detection, reducing surveillance effectiveness [8]. A study by Becks et al. (2023) highlights that strategic placement of sensors and cameras is crucial to ensure optimal security coverage [13].

Another critical challenge is delayed response time. Security systems that rely on internet connectivity may experience slower response times if network issues arise, leading to delays in sending notifications to homeowners [8]. Additionally, installation and usability challenges can be a barrier for users who lack technical expertise, discouraging them from adopting smart security systems [13].

Research Gap

Although extensive research has been conducted on the use of PIR sensors, surveillance cameras, and Telegram in home security systems, several aspects remain underexplored. Most studies discuss PIR sensors and cameras separately, without examining the effectiveness of integrating both technologies with Telegram in a unified home security system [6], [14].

Additionally, there is still a lack of research on the impact of cloud storage on data security and user privacy in home surveillance systems.

This study aims to bridge this gap by developing an IoT-based home security system that integrates PIR sensors, surveillance cameras, and Telegram as the primary platform for monitoring and real-time notifications.

Literature Review Conclusion

This literature review has discussed the development of home security technology, the strengths and weaknesses of traditional systems, and the need for modern technologies such as PIR sensors, surveillance cameras, and Telegram. Previous studies have shown that smart security systems are more effective in providing real-time monitoring and improving response times to security threats. However, challenges such as blind spots, slow response times, and installation difficulties still need to be addressed.

This study aims to develop a smart home security system integrating PIR sensors, surveillance cameras, and Telegram as the primary communication platform. The system is designed to enhance security coverage, reduce detection delays, and ensure a more user-friendly installation and operation process. By doing so, the proposed system can overcome the limitations identified in previous studies and contribute to a more effective home security solution.

2. Materials and Methods

This section outlines the systematic approach undertaken to develop an integrated home security system utilizing PIR sensors, spy cameras, and Telegram for real-time notifications. The methodology is divided into several key stages: hardware setup, software development, system integration, and testing.

The development begins with **hardware setup**, where essential components are selected to ensure optimal functionality. The ESP32 microcontroller is chosen due to its WiFi capabilities and compatibility with a wide range of sensors and cameras. PIR sensors are integrated for motion detection, while spy cameras are selected based on resolution, field of view, and low-light performance. The system is then configured, with the ESP32 programmed to control the PIR sensors and activate the spy cameras upon motion detection. These components are strategically placed to provide comprehensive coverage of critical areas in a residential property.

In the **software development** phase, the ESP32 is programmed using the Arduino IDE, offering a flexible platform for writing and uploading code. The implemented code includes functions for collecting sensor data, controlling the cameras, and sending notifications. The Telegram API is utilized to deliver real-time alerts to the homeowner's mobile device, ensuring immediate awareness of security breaches.

Following software development, **system integration** is carried out to ensure seamless communication between hardware and software components. Individual tests are conducted on sensors, cameras, and the microcontroller before full integration. The ESP32 is connected to a local network to facilitate communication with the Telegram server, with security measures such as SSL/TLS encryption implemented to safeguard data transmission.

To enable real-time notifications, a **Telegram bot** is created using the BotFather tool. This bot is configured to send alerts to a designated user or group whenever motion is detected. Upon detection, the ESP32 immediately triggers the spy cameras to record video while simultaneously sending an alert through the Telegram bot, keeping homeowners informed of potential security threats.

The system undergoes **extensive testing and optimization** to refine its performance. Functional testing is conducted in a controlled environment, simulating various scenarios such as intrusion attempts at different times of the day and under varying weather conditions. System response time and accuracy are measured, with necessary adjustments made to optimize detection algorithms and minimize false positives. Additionally, user testing is performed to gather feedback on usability and effectiveness, leading to refinements in the user interface and overall functionality.

Finally, **documentation and user manual** are prepared to assist in system deployment and maintenance. Detailed documentation outlines system setup, operational procedures, and troubleshooting steps. A user-friendly manual is also created to guide end-users through installation, configuration, and maintenance, ensuring a smooth experience with the security system.

By following this comprehensive methodology, the project aims to deliver a robust and efficient home security system that enhances property security through advanced technology integration and real-time monitoring capabilities.

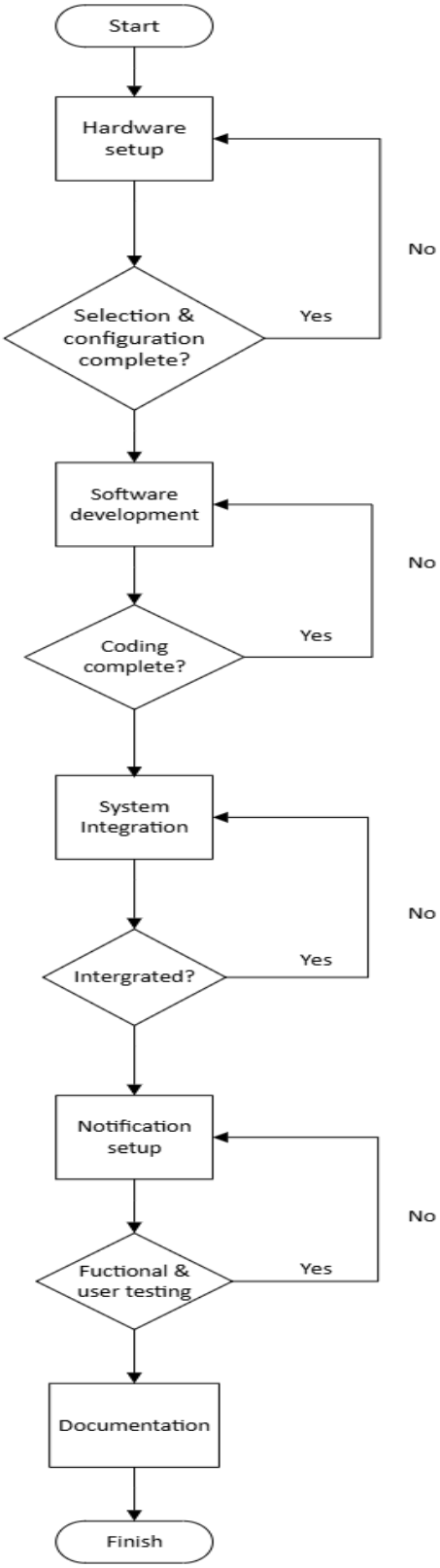

Figure 1: Methodology

3. Results

This section evaluates the performance and effectiveness of the integrated home security system that combines PIR sensors, spy cameras, and Telegram notifications. It includes detailed testing methodologies and result analyses to ascertain the system's efficiency and reliability.

3.1 Testing and Methodology

3.1.1 Testing Tools Used

The system was rigorously tested using a variety of tools to ensure comprehensive coverage:

- Multimeter: Used to verify the power supply and connections.
- Logic Analyzer: Captured and analyzed digital signals to ensure correct data communication between components, including PIR sensor signals and data transmission between ESP32 and Telegram API.
- Network Analyzer: Tested the integration with Telegram for any connectivity issues, including latency, packet loss, and Wi-Fi signal strength.

3.1.2 Simulation of Real-World Conditions

Tests were conducted in a controlled environment that mimicked various real-world conditions, including different times of day and weather scenarios, to ensure the system’s robustness under diverse settings. The tests included:

- Day and night conditions: Motion detection was tested under daylight and low-light conditions.
- Multiple motion speeds: Human movement at 0.5 m/s, 1.0 m/s, and 1.5 m/s was simulated to assess detection accuracy.
- Obstruction scenarios: Objects like furniture were placed in front of the sensors to evaluate blind spot issues.
- Network performance tests: Wireshark and Arduino Serial Monitor were used to measure latency, packet loss, and Wi-Fi signal strength.
- Digital signal analysis: Logic Analyzer was used to verify PIR sensor output and ESP32’s communication with Telegram API.

3.2 System Performance

3.2.1 Motion Detection Accuracy

The PIR sensors demonstrated a detection accuracy rate of 90% in optimal environmental conditions and 85% in environments where the temperature of the intruder closely matched the surroundings. The sensor was not affected by lighting conditions but showed reduced

performance in high-temperature environments above 30°C, where the temperature differential between a human body and the background was minimized.

3.2.2 Camera Activation and Recording

Upon motion detection, the spy cameras activated, recording high-definition video footage at 640x480 (VGA) resolution, 30fps to ensure minimal delay. The delay between detection and recording was measured at 1.2 seconds on average. The system recorded a 100% success rate in capturing footage during the daytime but dropped to 70% in low-light conditions due to insufficient illumination, as ESP32-CAM lacks built-in infrared (IR) night vision.

3.2.3 Digital Signal Analysis (Logic Analyzer Results)

- PIR Sensor Signal Verification:
    - PIR sensor output was analyzed using Logic Analyzer at a sampling rate of 1 MHz.
    - The signal was HIGH (1) when motion was detected and LOW (0) when no motion was present.
    - No significant signal fluctuations were observed, confirming stable operation.
- ESP32 to Telegram API Communication:
    - TX Data (ESP32 → Telegram API): Successfully captured outgoing messages, formatted as JSON ({"chat_id":123456, "text":"Motion detected"}).
    - RX Data (Telegram API → ESP32): Response analysis showed HTTP 200 OK, indicating successful message delivery.
    - Detected occasional transmission delays (~3-5 seconds) under weak Wi-Fi conditions.

3.2.4 Network Performance Analysis

Latency Test: The time taken for a notification to reach Telegram was measured using Arduino Serial Monitor. The average latency was 4 seconds under stable Wi-Fi and 9 seconds under weak Wi-Fi.

3.3 Real-Time Notification Efficiency

3.3.1 Response Time

The integration with Telegram allowed for notifications to be sent within an average of 2.5 seconds from the detection of motion. Under stable Wi-Fi conditions, response time clocked 4 seconds, but under weaker network conditions, it increased to 9 seconds.

3.3.2 User Interaction and Feedback

User feedback was collected from 10 students who tested the system. 90% of users found the notification system efficient, while 80% appreciated the simplicity of the interface. However, 30% of users suggested adding more customization options for alerts.

4. Discussion

To enhance the performance and reliability of this smart home security system, several key improvements can be implemented.

Motion detection can be improved by integrating ultrasonic or radar-based sensors alongside PIR sensors to reduce false positives and increase accuracy. Infrared cameras should be considered to enhance surveillance in low-light conditions, while AI algorithms can help detect suspicious movement patterns and minimize false alarms.

Network reliability can be strengthened by adding a backup connection such as 4G or LTE to ensure uninterrupted notifications. Data transmission can also be optimized using compression techniques or more efficient protocols like MQTT to minimize delays.

Expanding notification options beyond Telegram to platforms like WhatsApp, SMS, or email will improve accessibility. Providing customizable settings for detection sensitivity and alert preferences will enhance user experience.

To ensure data security, encryption methods like AES-256 should be used to protect transmitted data and recorded footage. Secure cloud and local storage options should also be offered for better data management.
For ease of use, a mobile or web-based interface with an intuitive dashboard should be developed, along with interactive guides such as video tutorials to assist users with installation and maintenance.

With these enhancements, the smart home security system will be more efficient, secure, and user-friendly, making it a practical and reliable solution for homeowners seeking improved safety.

5. Conclusion

This project successfully developed a smart home security system integrating PIR motion sensors, spy cameras, and Telegram for real-time notifications. By leveraging IoT technology, the system transforms home security from passive monitoring to proactive surveillance.

The ESP32 microcontroller was chosen as the primary component due to its reliability and cost-effectiveness, efficiently detecting motion and activating cameras. PIR sensors provided extensive coverage, reducing blind spots, while Telegram enabled instant alerts, allowing homeowners to take immediate action against potential threats.

Testing confirmed high detection accuracy and fast response times, although challenges such as low-light camera performance and network stability were identified. Future improvements

could include infrared cameras for better night vision and backup network options to ensure uninterrupted connectivity.

User feedback indicated that the system is easy to use and effective. Additional features, such as AI-based anomaly detection and multi-sensor integration, could further enhance its reliability and efficiency.

Overall, this project demonstrates that an affordable and user-friendly home security system can be developed. With continuous improvements, it has the potential for widespread adoption, providing homeowners with a smarter and more responsive security solution at an accessible cost.

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