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Multi-sensor security alarm system with Internet of Things (IoT)

Stephen T. Bascos
Capiz State University Main Campus
College of Education Graduate Programs
Roxas City, Philippines
Email: pen2bascos@gmail.com

Abstract: The advancement of Internet of Things (IoT) technology has enabled the development of intelligent automated security alarm systems. This developmental study aimed to develop a multi-sensor security alarm system integrated with IoT to enhance monitoring for establishments, homes, or buildings lacking dedicated security personnel. The device was designed to minimize false alarms, improve user control and awareness, and deliver timely alerts via a mobile app and SMS notifications. The research focused on describing the device's technical features, composition, and operating performance; evaluating its sensitivity in terms of distance, intensity, and varying internet speeds; assessing its connectivity through mobile app and SMS functions; and determining its acceptability in terms of technical features, composition, and operating performance.Data were collected using observation and evaluation sheets and analyzed using the arithmetic mean. The device was evaluated by 30 participants from the industry, end-user,and academe at Capiz State University. Results showed that the device was reliable, user-friendly, and effective across residential, commercial, and industrial settings. It included solar-powered backup for uninterrupted operation and allowed remote monitoring and control. The device accurately detected human presence at short distances and strong vibrations, though its sensitivity decreased at longer ranges and with lighter vibrations. It maintained functionality at low internet speeds and consistently sent alerts through mobile app and SMS. The modular design also supports future upgrades. Overall, the devicewas evaluated as "Very Acceptable" in terms of technical features, composition, and operating performance, confirming its potential as a dependable and adaptable security solution.

Keywords: Security Alarm System, Multi-Sensor Device, IoT Technology, Connectivity, Device Sensitivity

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INTRODUCTION

Over recent years, rapid technological advancements have profoundly impacted various aspects of daily life, including home and property security. Traditional alarm systems, which primarily relied on basic sound alerts and manual inspections, were once deemed sufficient. However, as modern threats grew more complex and sophisticated, these conventional systems proved increasingly inadequate. In response to society's demand for more effective and reliable solutions, the integration of smart technologies became essential in reimagining home security.

One of the most transformative developments in this domain has been the advent of the Internet of Things (IoT), enabling devices to communicate seamlessly within a connected network. Through IoT, homeowners gained the ability to remotely monitor their properties, receive real-time alerts, and exercise greater control over their security settings. Despite these advancements, many existing home security systems still face significant limitations.

A common issue involves frequent false alarms, often triggered by harmless movements such as those caused by pets or environmental changes, which can overwhelm users and lead to

unnecessary emergency responses. Additionally, some systems lack real-time updating features, resulting in delays in responding to genuine threats. Another major challenge is the lack of integration among various security devices. Many cameras, motion sensors, and alarm systems operate independently, reducing overall efficiency and complicating system management.

While innovations like smart cameras and mobile alert applications have been introduced to enhance home security, their effectiveness remains limited if these tools are not integrated into a unified platform. Without inter-device communication, even the most advanced technologies cannot reach their full potential (Yang & Wang, 2021).

To address these challenges, this study proposed a multi-sensor home security system leveraging IoT technology to seamlessly connect various sensors and components into a single, cohesive platform. The system incorporated motion detectors, vibration sensors, and reed sensors for door security, each tailored to detect specific types of security breaches. These sensors were linked to a central control unit accessible via a mobile application, which provided real-time notifications and SMS alerts to users. The app enabled homeowners to remotely monitor their properties, customize system settings—such as alarm volume and notification preferences—and arm or disarm the system conveniently from their mobile devices. This functionality was particularly useful in situations where the system was accidentally left disarmed or needed to be remotely disarmed for authorized access. Moreover, the app sent instant alerts when alarms were triggered, allowing users to respond swiftly and take appropriate action.

The primary objective of this research was to develop a reliable, responsive security solution suitable for homes and buildings that are frequently unoccupied and lacking on-site security personnel, thereby reducing vulnerability to intrusions. By providing immediate alerts and supporting rapid response, the system aimed to prevent or minimize security incidents effectively. This study sought to enhance traditional security measures through a more adaptive, integrative, and user-friendly approach.

Utilizing IoT technology and multiple sensors, the proposed system sought to decrease false alarms and bolster real-time monitoring and control. Designed to overcome the limitations of outdated security setups, this modern approach offered a practical, efficient, and technologically advanced solution suited to today's increasingly digital environment.

In light of these innovations, the researcher was motivated to develop this device to benefit end-users by minimizing false alarms and improving response times, thereby enhancing the system's overall effectiveness in preventing or mitigating security breaches. This study, titled "Multi-Sensor Home Security System with Internet of Things (IoT)," aims to deliver a more dependable and efficient security solution tailored for modern residences and structures.

Objectives of the study

The main purpose of this study was to develop a Multi-Sensor Security Alarm System with Internet of Things (IoT). Specifically, it aimed to:

1. describe the multi-sensor security alarm system with IoT in terms of technical features, composition and operating performance;
2. determine the sensitivity of multi-sensor security alarm system with IoT in terms of distance, intensity and varying internet speed;
3. determine the connectivity of the multi-sensor security alarm system with IoT in terms of mobile app and SMS notifications; and
4. find out the level of acceptability of the multi-sensor security alarm system with internet of things (IoT) in terms of technical features, composition, and operating performance.

METHODOLOGY

This developmental research explored the development, application and area of a multi-sensor security alarm system with Internet of Things (IoT). It covered the conceptualization, prototyping, testing and refinement of the whole device's system.The device was composed of three different sensors, motion, vibration, and reed sensors, all connected to a programmable microcontroller integrated with IoT technology. The system allowed users to monitor and control it remotely through a mobile app. Additionally, it sent Short Message Services (SMS) alert notifications via a Global System for Mobile Communications (GSM) module whenever internet connectivity was temporarily lost, ensuring that users could still manage their home security from anywhere.

The research scope examined how well the sensors worked together, how they performed under different internet speeds, and how easy the system was to use. The system ran on a low-power setup, using a battery-operated configuration supported by a solar panel as a backup charging system, along with an alternating current (AC) adapter and battery charge controller. It also included an automatic power transfer switch circuit used for the internet access point to ensure continuous connectivity even when power was temporarily lost.

Prototyping was carried out to turn the initial design into a working model of the IoT-integrated security alarm device. This involved assembling the required components, integrating IoT modules, and developing the firmware or software needed for communication, data collection, and control functions. The prototype went through repeated testing and validation to assess its sensitivity, connectivity, and ability to detect, monitor, and respond to security threats.

Testing involved circuit experiments, computer simulations, and real-world trials to check how well the device worked in different situations and environments. Data was collected on key aspects of the device's performance, including sensor activity and readings, alert notifications through mobile apps and SMS, power usage, response times, internet connection, and overall functionality. Simple statistical tools, such as binary response analysis and calculating the average (arithmetic mean), were used to understand the results and measure how well the device performed.

Evaluation was done to get feedback on how the device worked, how it was designed, and how well it performed. This helped the researchers find parts that needed to be improved in the next version. The results, methods, and findings of the study were written down in research reports, technical papers, and academic publications. These documents helped share what was learned, added to knowledge in electronics and IoT systems, and gave useful ideas for future research and development.

FINDINGS AND DISCUSSION

Technical features, composition and operating performance of multi-sensor security alarm system with Internet of Things (IoT)

The multi-sensor security alarm system with Internet of Things (IoT) functionality worked together to provide a reliable security solution. At the heart of the system, the ESP32 microcontroller acted as the brain, controlling the sensors, processing data, and connecting to the internet through Wi-Fi. This allowed the system to send alerts and notifications to users remotely,

keeping them informed of any security threats. The Global System for Mobile Communication (GSM) module sent Short Message Services (SMS)alerts when the alarm was triggered, which was especially useful in areas without internet access. The Passive Infrared Receiver (PIR)motion sensor detected human movement, helping to identify unauthorized access, while the vibration sensor sensed shocks or vibrations, such as those caused by a break-in attempt. The reed sensor (magnet switch) monitored doors and windows for any tampering, adding another layer of protection. The adjustable power regulator ensured that the system received a stable voltage, protecting it from any power surges or drops. A 12-volt lead acid battery powered the system, and a charge controller circuit prevented overcharging or deep discharge. Solar panels and a solar power controller provided renewable energy to charge the battery and power the system, even in areas with unreliable electricity. The auto power transfer circuit (Internet access point ATS) made sure that the system continued to work by switching between solar, battery, and main power supply when needed. The system was housed in a metal casing to protect the internal components from damage, weather, or tampering. All the parts were organized in a square box (control system case) to keep everything secure. When a security breach occurred, the siren alarm activated, sounding loudly and flashing lights to warn people nearby and scare off intruders. The adjustable delay circuit gave users time to disarm the system before the alarm went off. To prevent overheating, the exhaust fan kept the system cool, especially in closed spaces. Light emitting diode (LED) lighting provided light in the control area, and power and control system switches allowed users to turn parts of the system on or off as needed. The push button alarm stop button let users manually stop the alarm when necessary. This IoT-based multi-sensor security alarm system offered easy monitoring, reliable performance, and enhanced protection.

The multi-sensor security alarm system with Internet of Things (IoT) integration was designed with several technical features that enhanced its reliability, functionality, and ease of use. The device included a backup power supply supported by a solar-powered charging system, which ensured continuous operation during power outages. It supported real-time alerts through mobile app notifications and SMS, allowing users to stay informed about potential security threats instantly. With built-in IoT connectivity, users were able to monitor and control the system remotely through a mobile application, offering convenience and peace of mind from any location.

The system was versatile and suited for residential, commercial, and industrial applications. Its hardware components were modular, making them easy to upgrade or replace, which supported long-term use and adaptability to emerging technologies. The device could be shut down both manually and wirelessly, providing flexible control options in different situations. It utilized IoT technology for wireless communication between the system and the user interface, ensuring smooth and efficient interaction.

Furthermore, the sensors in the system were designed for low power consumption, allowing extended operation without the need for frequent maintenance. These sensors were carefully calibrated to detect specific events accurately and transmit signals reliably to the central controller. A key feature that set this system apart from others was its integration of solar-powered energy with smart IoT capabilities, offering a sustainable and intelligent solution for modern security challenges.

In terms of its composition, the multi-sensor security alarm system with Internet of Things (IoT) was designed with a focus on efficiency, durability, and maintainability. The device featured a programmable microcontroller and a Global System for Mobile Communication

(GSM) module that enabled wireless communication. Its components conformed to the appropriate specifications necessary for the system's intended purpose and reliable operation. Power was supplied through a power adapter and storage battery, with additional support from a solar-powered system, ensuring continuous energy availability and sustainability.

The system utilized eco-friendly materials and incorporated energy-efficient technologies wherever possible. It included a control unit compatible with both wireless and wired setups, allowing for flexible installation in a variety of environments. Most of the components were locally sourced, and the design made them easily serviceable and replaceable, which simplified maintenance and reduced long-term costs.

Internally, the parts were neatly arranged and clearly labeled, and all components were assembled in accordance with established security technology standards. The system also included functional electronic modules equipped with protective features to safeguard against damage and enhance longevity. All components were enclosed in a secure casing that provided protection from environmental elements and supported long-term, reliable use.

The multi-sensor security alarm system with Internet of Things (IoT) demonstrated strong operating performance, marked by reliability, responsiveness, and efficiency. The device had IoT connectivity that allowed remote monitoring, and it experienced few network outages that impacted its performance. Real-time alerts were promptly delivered to users via mobile apps or Short Message Services (SMS) notifications, ensuring timely awareness of security events.

Overall, the system performed its intended functions effectively, although there were occasional delays in response time. Its sensors detected accurately according to their intended functions and rarely triggered false alarms. The device was easy and safe to operate, and it was protected against unauthorized access, preventing control by unintended users. It was also capable of repetitive operation, maintaining stable functionality over extended periods.

The system was designed to use minimal energy, enabling long-term operation without frequent maintenance. It automatically activated the alarm when intrusions or forced entry attempts were detected. Through its mobile app interface and Global System for Mobile Communication (GSM) features, it monitored real-time status and alerts, and it detected security threats with high accuracy and minimal errors.

Sensitivity of the multi–sensorsecurity alarm system with Internet of Things (IoT)

Based on the comprehensive evaluation of the multi-sensor security alarm system with Internet of Things (IoT) capabilities, the following synthesis captures its overall performance across different operational parameters:

The system demonstrated high sensitivity to human presence at close range, with a 100% detection rate at 1 meter. However, its accuracy declined at greater distances, achieving only 80% at 2 meters and 60% at 3 meters. These results underscore the device's reliability for short-range monitoring but suggest reduced effectiveness in wider or more open areas, possibly due to signal limitations or environmental obstructions. Supporting literature from Kahya et al. (2023), Jukić et al. (2023), and Patel (2021) affirmed that similar sensor systems exhibit peak sensitivity at close range but drop in performance with distance.

When tested for sensitivity to vibration intensity, the device again showed optimal performance under strong vibrations, detecting all ten incidents. However, detection fell to 50% at medium intensity and failed completely under low-intensity vibrations. This indicated that the device was well-suited for identifying strong impacts but might miss subtler disturbances, such

as cautious break-in attempts. These findings were consistent with studies by Rasool et al. (2019), Zhang et al. (2021), and Smith et al. (2020), all of whom emphasized the challenge of capturing low-level vibrations in security systems.

In terms of internet speed sensitivity, the device was capable of sending alerts even at speeds as low as 100 kbps, with a 30% success rate, improving to 50% at 151–200 kbps and reaching 80% success at speeds above 200 kbps. This suggested that the system could operate under minimal bandwidth but performed more reliably with faster connections. Prior research by Patel et al. (2020), Singh et al. (2021), and Sharma & Agarwal (2022) validated the device's capacity to function in low-bandwidth environments, though with compromised reliability.

Regarding connectivity performance, the device successfully established connections with the mobile app and delivered SMS alerts in all ten trials, yielding a 100% success rate. This consistency highlighted the system’s robust remote monitoring capabilities and real-time alert mechanism. The results mirrored those in studies by Patel et al. (2021), Singh & Gupta (2020), and Kumar et al. (2022), who found that IoT-integrated security systems with SMS and app notifications significantly improved user awareness and response time.

The multi-sensor security alarm system with IoT capabilities proved to be highly effective at close-range human detection, strong vibrations, and stable internet conditions. While it offered reliable mobile and SMS connectivity, its performance declined with distance, weaker vibrations, and slower internet speeds. These insights suggest that while the system is well-suited for confined or controlled environments, enhancements such as sensor calibration, additional units, or complementary technologies are recommended for broader and more nuanced security coverage.

General acceptability of multi-sensor security alarm system with Internet of Things (IoT)

Based on the evaluation result for the acceptability of multi-sensor security alarm system with Internet of Things (IoT) in terms of the technical features, the data showed in the Table 8 that the average mean result for the feature was 4.42 and verbally interpreted as Very Acceptable.This implied that the system’s high acceptability ratings across technical features suggested that users considered reliable, easy to use, and well-suited to their needs. However, the slightly lower rating for the combination of sustainability, smart features, and user-friendly design implied that users had valued practical functionality over innovation. While the advanced features were appreciated, users had been more focused on meeting their immediate security needs rather than on cutting-edge qualities. Therefore, this suggested that future improvements should have focused on balancing innovation with practicality to boost user satisfaction.

For the acceptability of multi-sensor security alarm system with IoT in terms of the composition got an average mean result of 4.45 and verbally interpreted as very acceptable.
This implied that the high ratings across all components of the device indicated that users found the design to be both practical and reliable. The positive feedback on features like the programmable microcontroller, Global System for Mobile Communication (GSM) module, and eco-friendly power system highlighted the importance users placed on the device's functionality, flexibility, and energy efficiency. However, the slightly lower score for the outer enclosure suggested that while it was still considered acceptable, there might be room for improvement in terms of durability or design to further enhance the system's longevity. Overall, these results confirmed that users appreciated the well-thought-out construction and attention to both performance and ease of maintenance, which could lead to greater user satisfaction and broader

adoption.On the other hand, the acceptability of multi-sensor security alarm system with Internet of Things (IoT) in terms of the operating performance got an average mean result of 4.42 and verbally interpreted as very acceptable.

The results implied that the multi-sensor security alarm system with IoT connectivity was highly acceptable and reliable, indicating strong user satisfaction. The system performed well in key areas such as real-time alerts, sensor reliability, and ease of use, with high scores in each category. Despite occasional network outages, the system's IoT connectivity was still considered dependable, and users found it effective for everyday security needs. The device was viewed as highly reliable, user-friendly, and energy-efficient, positioning it well in the IoT security market. Despite occasional minor delays and network outages, the system's proactive alarm features and minimal false alarms made it suitable for widespread adoption. Its eco-friendly design further aligned with growing consumer demand for sustainable products, though performance improvements could have enhanced its appeal. The system provided a robust and sustainable security solution, with significant market potential.

CONCLUSION

The multi-sensor security alarm system with IoT integration as described, proved to be a reliable, functional, and user-friendly solution. It featured a solar-powered backup for uninterrupted operation, real-time alerts via mobile app and SMS, and remote monitoring and control for various environments. The system's modular design allowed for easy upgrades and replacements. Designed for efficiency and durability, it used eco-friendly materials, low-power sensors, and energy-efficient technologies. The system supported both wireless and wired installations and was built with locally sourced components for easy servicing, ensuring reliable, long-lasting performance.

The device demonstrated dependable performance and sensitivity, with accurate human presence detection at short distances and strong vibration detection. Although its effectiveness decreased at longer distances and with lighter vibrations, it still performed well in detecting significant disturbances. Additionally, the system's ability to function reliably at various internet speeds confirmed its resilience in typical mobile data and internet connectivity conditions.

The device consistently connected to the mobile app and sent SMS security alerts in all tests, confirming its reliability in providing remote monitoring and timely security updates.

Generally, the device's technical features, composition, and operating performance were rated as very acceptable, confirming its suitability as a reliable, energy-efficient, and sustainable security solution.

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