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User-Friendly Smart Security System using ESP32 in Rental Rooms

Murphy T. Saumat[1], Crianne Herc C. Codate[2], Rey P. Dayoc[3]
College of Engineering and Technology, Misamis University

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Abstract *– Face-to-face classes have compelled students to reside in temporary shelters, especially those who study far from home. Being in a new setting with unfamiliar individuals, students become more susceptible to theft, lacking any means to safeguard the privacy of their possessions. Technological advancement brought forth an era of automation where everything runs automatically without the need for human intervention. With knowledge of these advancements, the researchers made use of such technology in a security system. This paper developed a smart security system that can be applied in rental rooms, dormitories, or any establishment that caters to different individuals living in one room. The paper has five stages in gathering necessary data: room inspection, locating the optimal placement of sensors, wireless node system, system test, and data analysis. This data is used to determine the effectiveness of the smart security system. The study shows that smart security system response time is controlled by signal strength, not distance. The smart security system's performance, efficiency, and efficacy depend on the user's smartphone signal strength. The researchers concluded that the smart security system safeguards user assets, and the alarm alerts personnel without user intervention.*

Keywords *– Automation, Blynk, Espressif32 (ESP32), Internet of Things, Security System.*

INTRODUCTION

Security systems have become essential to the community and industry. Security Systems are designed to provide protection and defense within a designated establishment or property against intruders, trespassers, and burglars. Murder, homicide, physical injury, and rape has lower case rates in 2022 compared to 2021 except for theft which has risen by 9.19 percent from 4,318 to 4,331 cases, and robbery which has risen by 0.30 percent from 10,344 to 11,295 cases which makes it the common crime in the Philippines (Pinlac, 2022). Students are prone to this kind of crime such as theft, especially students who temporarily live in rental rooms or boarding houses that only rent in bed spacers. There is no more space for privacy for the students and their materials, stuff, belongings, and essential items.

ESP32, Espressif32, in this study, is used as a microcontroller which is the same as Mustafa et al. (2023) in the setup of home automation, Kumar et al. (2022) in the setup of smart lock, and Baqir (2023) in the setup of security. As stated by Mustofa et al. (2023), the ESP32 outperforms its close cousin, the ESP8266, thanks to additional features like a CPU core, faster Wi-Fi, Bluetooth (BLE), touch sensitivity pins, built-in hall effect sensors, and a temperature sensor. It has also been added that the Arduino Uno has inefficient power consumption, making it unsuitable for use with a battery, whereas the ESP32 can run for an astonishingly long time on batteries, making it perfect for developing countries. General Purpose Input/Output (GPIO) pins on the ESP32 are greater than on the ESP8266.

Security is the main goal of this smart security system which is in line with the goals of Kethinen and Pradeepin (2023) with their security surveillance and automatic water system that can regulate irrigation and provide security by surveillance of the field. Baqir (2023) discussed his home automation technology which is fully functional and addresses a variety of real-world applications. These security systems have the same goal, to provide safety and protection, but applied differently. Literature shows different security systems and their application that uses microcontrollers which correlates

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with this interactive security system that will be applied in boarding houses and dormitories.

Objectives Of The Study

Security systems are indeed crucial which is why many upgrades, innovations, and applications of such systems are present. The application though is quite broad and not specified like the system of Baqir (2023). The research filled that gap by designing a smart security system and applying it specifically in boarding houses or dormitories where students are mostly present, and theft is frequent as stated by Pinlac (2022). Because their valuable goods will be safeguarded by this security system, students who reside a significant distance from their families will be able to have a greater sense of relief. The investigation was carried out inside the researchers' local area, specifically in rental rooms located in Ozamis City, Philippines. The system design is made to be adaptable enough to be deployed in any room since the researchers wanted to make sure the intelligent security system offered sufficient security. In addition, the response time is reviewed to confirm that the notification is being sent by the system in a timely manner.

Materials And Methods

System Design

The smart security system is experimental. Therefore, the system was tested in different environments and parameters to determine the system's effectiveness. Figure 1 shows the stages taken to obtain the necessary data. For the interactive security system to be used in any room, room inspection is the first stage to take as shown in Figure 1. To optimize sensor placement based on sensor activation, Building Information Modeling (BIM) method is used which considers the room size, the sensor features, and the neighbor zones that must be covered by two different combinations of sensors (Bachouch et al., 2023). According to Bachouch et al. (2023), by integrating the building digital model designated by BIM, optimal sensor placement in a smart home is achieved. Wireless sensor networks (WSNs) have expanded significantly in recent years and hold great promise for use in a variety of fields, including the military, environment, and health (Bensaleh et al., 2020). The wireless node system in the prototype security system in Figure 1 is made possible by sensors that are linked to a smartphone.

Shown in Figure 2 is the block diagram that contains the components used in the security system. The block diagram is not the smart security system because it is still not connected to the internet. Rather, the block diagram shows the base of the smart security system and discusses its components.

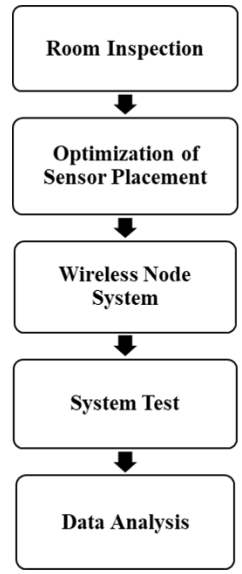

Fig. 1. Block Diagram of Research Design.

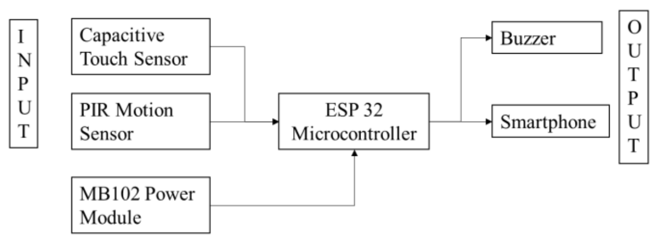

Fig. 2. Block Diagram of the Security System.

Component Selection

ESP32 shows the central panel that is programmed using C/C++ to perform multiple commands using the capacitive touch and motion sensor input data and process them to achieve the desired outcome. A built-in capacitive touch sensor in the ESP32 is used to send a signal when it is touched. It is placed and utilized in cabinets and detects any possible theft to protect belongings and possessions. The Passive Infrared Sensor (PIR) motion sensor is a component used to monitor and detect movement changes in the surroundings. It is used in the smart security system to detect any possible intrusions and break-ins in a specific room. For the power supply, an electronic device is used to convert the AC supply to 5V and the 3.3V DC supply for other components to operate, such as the ESP32, sensors, and buzzer. The smartphone is the device used by the owner to receive notifications and control the security system via a wireless connection. The smartphone must be downloaded with a Blynk app to monitor and keep track

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of the system. For the external alarm, an electronic device that emits sound when it is supplied in the smart security system, it emits sound when unusual activities or disturbances are detected by sensors. The buzzer can be controlled by the owner. For the software components, the Blynk is an IoT platform installed in a smartphone that is used to provide notification for possible theft and data transfer from the owner's device to the ESP32 and vice versa to have control over the security system. Software development refers to the program ESP32. The program is reprogrammed if adjustments are needed to the smart security system. The development and programming of the ESP32 are done using the Arduino Integrated Development Environment (IDE), and the Blynk application is used so that the system is controlled via smartphone through the application. The interface of the Blynk application is modified depending on the desired system.

Hardware Integration

Integration of the smart security system to the internet, through the ESP32, made the system IoT based and can be controlled and monitored using the Blynk app via smartphone. Hardware Integration is crucial for this system to be able to call it a smart security system which is shown in block diagram in Figure 2.

The MB102 Power Module is the heart of the system as it provides the needed supply for the components to operate such as the ESP32, PIR motion sensor, buzzer, etc. The ESP32 act as a center panel of the smart security system. ESP32 require a program to execute such action. The inputs coming from the different sensors are processed in the ESP32 according to the program of the user. Capacitive touch sensor and motion sensor are used to monitor any changes and send input signals to the ESP32 whenever a change has occurred. When a change is detected by the sensors, the ESP32 triggers the buzzer to alert the nearby people and provide immediate action, it also alerts the owner with a notification through Blynk app if the smartphone is connected on a Wi-Fi/data connection. Moreover, the owner can still control the system by stopping the buzzer through his/her smartphone with Blynk.

Software Development

Figure 3 presents the flowchart of the smart security system, specifically its process involved. The security system starts when either one of the sensors has detected changes in specific parameter. As sensors detect these abnormalities, a notification is sent to the occupants through their gadget via any means of mobile connection. Additionally, the occupants themselves have the option to stop or continue the alarm system when it is triggered. When the alarm system is stopped, the system returns to normal function.

System test is the most crucial data gathered in all the stages shown in Figure 1. This is the stage where the effectiveness of the smart security system is tested. The system test went through different parameters to determine which situation will the system perform best, and which situation will the system perform poorly. Response-Time is the focus of the test but alongside it is the signal strength and distance of both the smart security system and the smartphone.

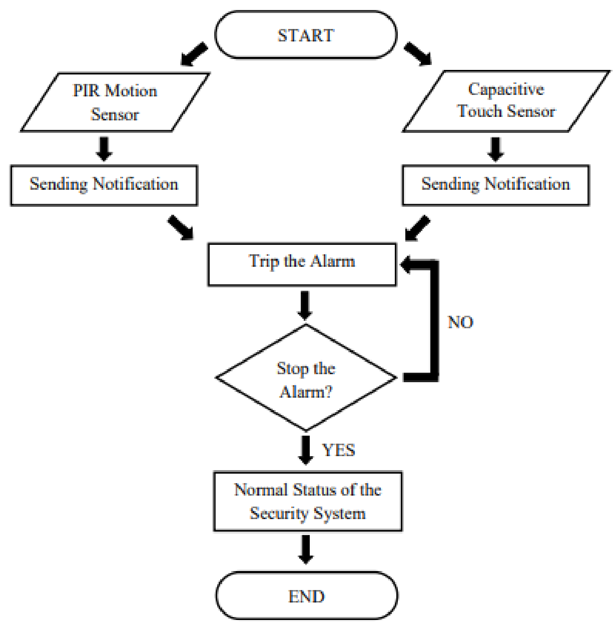

Fig. 3. Flowchart of the Smart Security System.

Results and Discussion

Hardware Construction

The test commenced by testing the components, preparing the Blynk Interface, hardware and software integration.

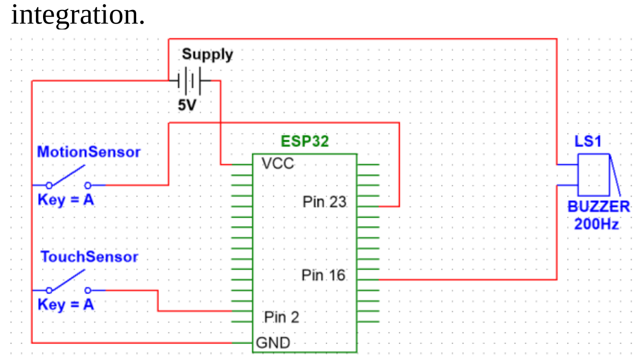

Fig. 4. Schematic Diagram of the Smart Security System.

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The circuit shown in Figure 4 is the actual connection of the smart security system. The schematic diagram shows where the supply, sensors, and buzzer are specifically connected to the ESP32. Motion sensor is connected to Pin 23 while touch sensor is to Pin 2 and both sensors have the same output which is the buzzer connected to Pin 16.

The sensors used in the security system were the motion and touch sensor. The motion sensor was tested by supplying a 3.3 voltage and is in series with an Light-Emitting Diode (LED) for indication. While the capacitive touch sensor is built-in in ESP32, the microcontroller is programmed so that when the touch sensor is triggered, the LED indicator is lit up

Software Structure

The code for the microcontroller was done using Arduino IDE software where the researchers developed and reprogrammed the code needed to run the smart security system then uploaded it to the microcontroller. Blynk application is used to connect the microcontroller to a smartphone. Also, the application is where the user can control the smart security system. Figure 5 shows the interface of the Blynk application, the buttons each controls a sensor whether to activate the sensors or turn of the sensors, also the buttons are the controls for the alarm system. The numbers displayed are the actual values of the sensors, when the value of touch sensor drops below 50 then the sensor triggers, and when the value of the motion sensor changes to one then the sensor triggers. The red circles are indications when the sensors are triggered.

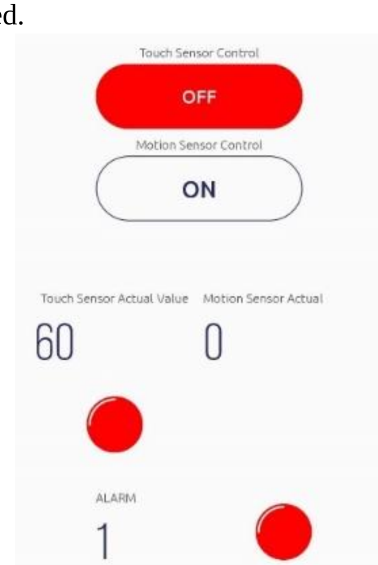

Fig. 5. Blynk Interface for the Smart Security System.

Assembly of all the components for the smart security system began on a breadboard where multiple trial and error were run. Shown in Figure 6 is the smart security system on a breadboard where the components encircled in red are the sensors, encircled in blue is the ESP32, and the LEDs are an indication that the sensors are being triggered.

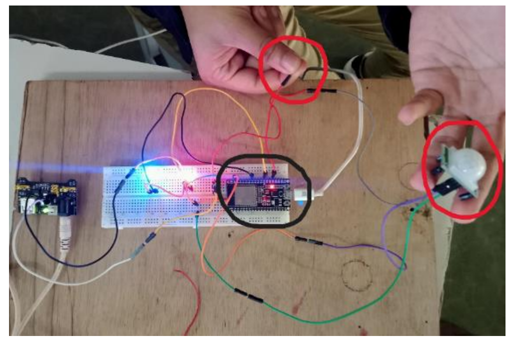

Fig. 6. Smart Security System on a Breadboard.

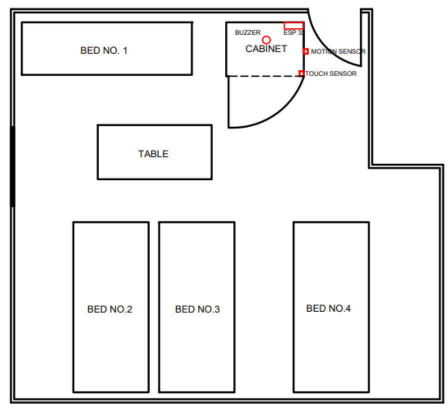

Fig. 7. Actual Placement of Smart Security System.

After determining that the smart security system is working, installation of the said system commenced in a boarding house located at Barangay Aguada, Ozamiz City Misamis Occidental. Figure 7 is the actual placement of the smart security system inside the room, ESP32 along with the MB102 Power Module is inside the cabinet. While the motion sensor is by the side of the cabinet and facing the door opening area, the capacitive touch sensor is installed along the locking system of the cabinet, and the actual placement of the buzzer, the alarm of the system, is placed above the cabinet, hidden from sight.

Table 1 shows the data under varied signal strength when the motion sensor is triggered and time it takes received the notification under three trials where the control variable in these trials is the distance. The table outlines the time it takes for a notification to be received under three different trials' locations, each conducted at

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a constant distance to serve as the control variable. The findings indicate a clear relationship between signal strength and system responsiveness. Stronger signal strengths resulted in quicker notification times, confirming the expectation that a robust signal is crucial for optimal system performance. By keeping the distance constant in these trials, the researchers were able to isolate the effect of signal strength, thereby providing compelling evidence for its role in affecting the system's response time.

Table 1. Motion Sensor's Response-Time (under varied Signal Strength)

Signal Strength (Motion)	Trial 1		Trial 2		Trial 3	
	A	B	A	B	A	B
Strong - Strong	07:13:31	07:13:32	07:35:47	07:35:47	07:59:19	07:59:20
Strong - Weak	07:18:18	07:18:21	07:42:04	07:42:08	08:02:36	08:02:42
Weak - Strong	07:22:26	07:22:31	07:46:33	07:46:36	08:08:07	08:08:11
Weak-Weak	07:26:08	07:26:18	07:53:22	07:53:34	08:16:31	08:16:41

Note: A – Triggered, B – Received.

Table 2 presents the time delay data in each trial based on the difference of time triggered and the notification time when the motion sensor is triggered under varied signal strength. When the system operates under strong signal conditions, the time delay between the sensor being triggered and the notification being received is minimized, indicating higher system efficiency. Conversely, under weak signal conditions, the system experiences a longer time delay, which could potentially compromise the effectiveness of the security system. This data is crucial as it directly impacts the system's reliability and responsiveness, two key parameters for any security system.

Table 2. Motion Sensor's Time Delay (under varied Signal Strength)

Signal Strength (Motion)	Time Delay		
	Trial 1	Trial 2	Trial 3
Strong - Strong	1	0	1
Strong - Weak	3	4	6
Weak - Strong	5	3	4
Weak- Weak	10	12	10

Table 3 shows the data under varied distance when the motion sensor is triggered and time it takes received the notification under three trials where the control variable in these trials is the signal strength.

Table 4, 5, and 6 show the different parameters to test whether there is a significant difference between the time delay. As shown, the value of P-value is 3.09×10^{-5} which is less than 0.5. The results confirm initial expectations, revealing a significant difference in time delays based on the P-value of 3.09×10^{-5}, which is well below the commonly accepted threshold of 0.05 for statistical significance. This low P-value indicates that the variations in time delay are not due to random chance but are significantly influenced by the strength of the signal. In other words, the strength of the signal has a measurable and statistically significant impact on the system's responsiveness. This finding underlines the importance of maintaining strong signal strength for optimal system performance and validates the research hypothesis that signal strength is a critical factor affecting the time delay in the smart security system.

Table 3. Motions Sensor's Response-Time (under varied Distance)

Distance (Motion)	Trial 1		Trial 2		Trial 3	
	A	B	A	B	A	B
60 meters	15:27:16	15:27:16	15:34:50	15:34:50	15:41:29	15:41:30
305 meters	09:11:32	09:11:33	09:18:24	09:18:25	09:26:18	09:26:19
39500 meters	13:20:25	13:20:25	13:29:06	13:29:07	13:38:14	13:38:14

Note: A – Triggered, B – Received.

Table 4. ANOVA Test Results in Motion Sensor (under varied Signal Strength)

Source of Variation	Sum of Square	Degrees of Freedom	Mean Square	F-value	P - value
Between Groups	156.92	3	52.30	41.84	3.09e-05
Error	10	8	1.25		
Total	166.92	11			

Table 5. ANOVA Test Results in Touch Sensor (under varied Signal Strength)

Source of Variation	Sum of Square	Degrees of Freedom	Mean Square	F-value	P - value
Between Groups	130.92	3	43.63	43.64	2.64e-05
Error	8	8	1		
Total	138.92	11			

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Table 6. ANOVA Test Results in Touch Sensor (under varied Distance)

Source of Variation	Sum of Square	Degrees of Freedom	Mean Square	F-value	P - value
Between Groups	0.22	2	0.11	0.33	0.729
Error	2	6	0.33		
Total	2.22	8			

CONCLUSION AND RECOMMENDATION

The study demonstrates the efficacy of a smart security system that can be adaptable to various room layouts and offers real-time protection. The system's response time is not significantly affected by distance but is highly dependent on signal strength. The system is not only effective in safeguarding valuable possessions but also features an automatic alarm to alert individuals within the premises. Designed to be flexible, expandable, and cost-effective, the system leverages the capabilities of the ESP32 chip. Future research is recommended to explore additional areas with inadequate security, integrate more sensors for enhanced protection, fully utilize the features of the ESP32, and identify superior IoT platforms.

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CONTACT INFORMATION

NAME: MURPHY T. SAUMAT
CONTACT NO: +639157371048
EMAIL ADDRESS: MURPHY.SAUMAT@GMAIL.COM