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Home Security System Based on Raspberry Pi and PIR Sensor Using WhatsApp Messenger

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ABSTRACT

Home security is a crucial factor for everyone to protect property and ensure the safety of their family. Along with technological advancements, home security systems have evolved from simple mechanisms to sophisticated devices integrated with the Internet of Things (IoT). One of the widely used technologies in such systems is the Raspberry Pi, a small, affordable, and flexible computer capable of controlling other devices through its General Purpose Input/Output (GPIO) pins. The Passive Infrared (PIR) sensor also plays a vital role in home security systems due to its ability to detect human movement by sensing changes in infrared radiation emitted by the human body. By utilizing PIR sensors, security systems can detect motion inside or around the house, potentially indicating threats such as burglary attempts. In addition, fast and efficient communication is essential in security systems. WhatsApp Messenger, as one of the most popular instant messaging applications, offers convenience in sending alerts or notifications directly to the user's device. The integration of Raspberry Pi, PIR sensors, and WhatsApp Messenger can create a home security system that is not only cost-effective but also capable of delivering real-time notifications to homeowners. By combining Raspberry Pi and PIR sensors with WhatsApp as a communication medium, the system offers advantages in cost, ease of installation, and efficiency in delivering alerts without requiring additional complex hardware. Therefore, this research aims to design and implement a Raspberry Pi and PIR sensor-based home security system with notifications sent via WhatsApp Messenger.

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1. INTRODUCTION

Motor vehicle theft, particularly motorcycle theft, remains one of the most prevalent crimes in Indonesia. Statistical data from the Central Bureau of Statistics [1] and the Indonesian National Police indicate that such incidents occur across both urban and rural areas, with increasingly sophisticated methods employed by perpetrators. Motorcycles are frequently targeted due to their practicality, high mobility, strong resale value in black markets, and significant demand for second-hand spare parts. These factors make motorcycles an attractive target for criminals, while theft often exploits owner negligence, such as parking without additional security devices or leaving vehicles unattended in poorly monitored environments [2].

Reports from the Indonesian National Police (Bareskrim Polri) highlight the magnitude of this issue. Between January and December 2024, more than 25,000 motorcycle theft cases were recorded nationwide, with theft crimes constituting nearly 10% of all criminal offenses [3]. These alarming numbers underline the urgent need for innovative security measures that can help minimize risks and prevent losses for vehicle owners [4].

Previous studies have attempted to develop home and vehicle security systems using various sensors and communication platforms [5]. For example, researchers have explored Raspberry Pi-based motion detection systems integrated with PIR sensors and facial recognition technologies to improve monitoring accuracy [6][7]. Other works have utilized instant messaging applications such as *Telegram Messenger* to send real-time alerts and images when suspicious activities were detected inside a monitored area [8]. While these approaches provide valuable contributions, limitations remain, particularly in terms of data accuracy, user convenience, and real-time notification capabilities [9].

Recent technological advancements in the Internet of Things (IoT), microcontrollers, and wireless communication systems offer new opportunities to design more intelligent, cost-effective, and user-friendly security solutions [10]. By integrating motion detection sensors, microcontrollers, and communication applications such as WhatsApp Messenger, vehicle owners can receive real-time alerts directly on their smartphones whenever suspicious activity is detected [11]. Unlike traditional security devices, this integration provides not only protection but also acts as a deterrent to potential criminals by reducing opportunities for unmonitored theft [12].

This study aims to design and implement a motorcycle security system based on microcontrollers and PIR sensors, integrated with WhatsApp Messenger as a communication platform. The proposed system is expected to enhance responsiveness, improve safety, and reduce theft risks by delivering real-time notifications to vehicle owners. Furthermore, this research contributes to the growing body of literature on IoT-based security applications by demonstrating the feasibility of integrating low-cost hardware with widely used communication platforms to create an efficient and reliable security solution and this research is very important because it can help maintain home security when the homeowner is not at home.

2. METHOD

In this section, a home security system based on Raspberry Pi and PIR sensors is designed. The system operates by detecting human motion through the PIR sensor. When motion is detected, the system automatically captures an image using the connected camera module. The captured image is then transmitted to the user via WhatsApp Messenger as a real-time notification.

The method includes three main stages:

1. System Design – This stage involves the planning and configuration of hardware components, including the Raspberry Pi, PIR sensor, and camera module, as well as the integration of the WhatsApp messaging API for communication.
2. System Operation – This describes the working principle of the device, in which the PIR sensor continuously monitors for motion, triggers the Raspberry Pi upon detection, and executes the image capture and transmission process.
3. System Testing – At this stage, the prototype is tested under different environmental conditions to evaluate its accuracy in motion detection, response time in sending notifications, and reliability of real-time communication.

Through these stages, the system is expected to produce the desired output, namely an effective, low-cost, and real-time home security mechanism that provides direct alerts to the homeowner.

Table 1. Component functions

SN	Process	Component/Function	Description
1	Sensor Data Processing	Raspberry Pi [12]	Reads input from the camera and PIR sensor to acquire data.
2	Motion Detection	PIR Sensor HC-SR501[13]	Detects whether or not motion is present.
3	Warning	LED Lamp & Buzzer[14]	Provides an alert signal using light and sound.
4	Path Activation	Raspberry Pi[15]	Controls and monitors one of the three connected devices.
5	Monitoring	HSmart Cam Camera[16]	Captures images and transmits them to WhatsApp with a visual display.

In Table 1, the components used in this research are presented along with their respective functions, descriptions, and processes. Based on Table 1, Figure 1 on the following page illustrates the visualization of how the proposed home security system operates.

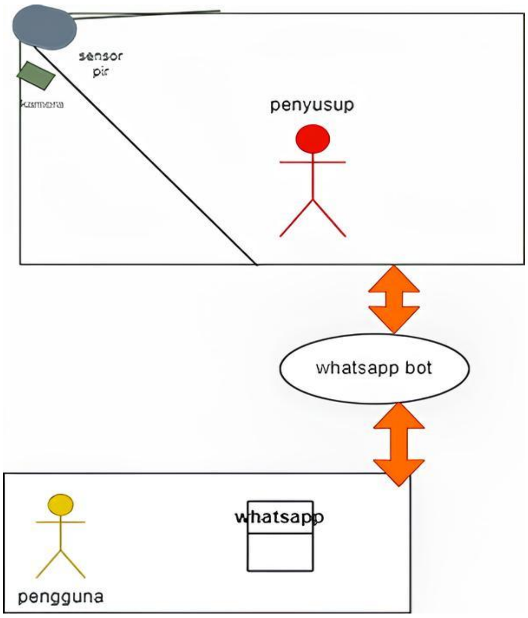

Figure 1. Visualization of home security system

2.1 Raspberry PI

The Raspberry Pi is a small single-board computer (SBC) designed primarily for educational purposes and experimental projects. This device can be utilized in a wide range of applications, including learning programming, developing electronic projects, and running lightweight servers. The Raspberry Pi is typically equipped with an ARM-based processor, RAM memory, USB ports, HDMI output, and the capability to connect to a network via Ethernet or Wi-Fi[17][18][19].

(a) **(b)**

Figure 2. (a) Raspberrry PI (b) Raspberry PI camera module

3. RESULTS AND DISCUSSION

In this section, the author presents the experimental results, focusing on the research problem formulation. The analysis emphasizes the relationship between the distance of the detected object and the quality of the image captured by the camera.

3.1 Test Scenarios

3.1.1 Lighting Measurement

The first stage is to measure the lighting used in the system, which involves testing different lighting sources at varying distances. The measurements were taken in terms of time and illuminance (lux) as the input parameter[20][21][22].

Table 2. Lighting Test Results

No	Distance to Camera (cm)	Light Source	Light Intensity (Lux)	Detected (Yes/No)
1	50	LED Lamp 5W	105	Yes
2	50	LED Lamp 10W	310	Yes
3	50	White Neon Lamp	509	Yes

No	Distance to Camera (cm)	Light Source	Light Intensity (Lux)	Detected (Yes/No)
4	50	Spotlight 15W	715	Yes
5	100	LED Lamp 5W	131	No
6	100	LED Lamp 10W	355	Yes
7	100	White Neon Lamp	511	Yes
8	100	Spotlight 15W	745	Yes

Table 3. Lighting Load Test Results

Lighting Condition (Lux)	Load (Watt or Setting)	Detection Result	Notes
105	50% load	Yes	Dim lighting
310	75% load	Yes	Normal
511	100% load	Yes	Bright lighting

3.1.2 Distance Testing with Objects

The Raspberry Pi and PIR sensor were tested to determine the maximum detection distance. When the PIR sensor successfully detected motion, the reading was processed by the Raspberry Pi and the result was transmitted to WhatsApp Messenger. Successful detections were also displayed as notifications on WhatsApp[22].

Table 4. Distance Testing with Objects

No	Distance Between Camera and Object	Sensor Response (Yes/No)	Detection Result
1	1 m	Yes	Detected
2	3 m	Yes	Detected
3	5 m	Yes	Detected
4	7 m	No	Not Detected

Figure 3. Object Detection Test

3.1.3 Environmental Condition Testing

A. Morning Conditions

Table 5. Distance Testing in Morning Conditions

No	Distance (m)	Environmental Condition	Morning Response (Yes/No)
1	1	Detected	Yes
2	3	Detected	Yes
3	5	Detected	Yes

Figure 4. Testing in Morning Conditions

B. Afternoon Conditions

Table 6. Distance Testing in Afternoon Conditions

No	Distance (m)	Environmental Condition	Afternoon Response (Yes/No)
1	1	Detected	Yes
2	3	Detected	Yes
3	5	Detected	Yes
4	7	Not Detected	No

Natural daylight conditions (morning or afternoon) support facial detection performance effectively, but only up to a distance of 5 meters. Beyond this range, the system failed to detect facial features. For more reliable detection beyond 5 meters, the use of a higher-resolution camera or enhanced detection algorithms is required[23].

Figure 5. Afternoon Condition Testing

C. Night Condition

Table 7. Night Condition Testing Results

No	Distance (m)	Environmental Condition	Night Response (Yes/No)
1	1	Detected	Yes
2	3	Detected	Yes
3	5	Detected	Yes
4	7	Detected	Yes

Based on the test results at various distances (1–7 meters) during both night and morning conditions, the facial detection system demonstrated consistent and reliable performance. Facial detection was successfully achieved at all tested distances, indicating that the system can function effectively under different lighting conditions. This suggests that the camera used may be equipped with supporting features such as artificial illumination or night mode, which help maintain detection quality even in low-light environments[24].

Figure 6. Night Condition Testing

D. Rainy Weather

Table 8. Rainy Weather Testing Results

No	Distance (m)	Environmental Condition	Rainy Response (Yes/No)
1	1	Detected	Yes
2	3	Detected	Yes
3	5	Detected	Yes
4	7	Detected	Yes

Based on the results presented in Table 8, the facial detection system successfully detected objects at all tested distances, ranging from 1 to 7 meters, during rainy conditions. These findings indicate that the system can operate optimally under rainfall, maintaining stable detection performance across various distances.

The results further demonstrate that environmental factors such as rain did not significantly disrupt the system's ability to capture and process facial data. This suggests that the camera and supporting algorithms are sufficiently robust to handle weather-related challenges, ensuring reliable functionality even in outdoor environments with rainfall [25][24].

Figure 7. Testing Under Rainy Conditions

3.2 Results

The testing phase was conducted to evaluate the performance of the proposed home security system in relation to the research problem [26]. The main focus was on analyzing how the distance between the object and the camera affects the quality of the captured images and the accuracy of motion detection by the PIR sensor [27]. Several test scenarios were designed by varying the distance of the moving object, ranging from short to long distances, to determine the system's reliability under different conditions.

3.2.1 Calculation of PIR sensor testing accuracy

Table 9. PIR sensor accuracy test results

No	Distance (m)	Trials	Correct Detection	Incorrect Detection	Accuracy (%)
1	1	5	5	0	100%
2	2	5	5	0	100%
3	3	5	4	1	80%
4	4	5	4	1	80%
5	5	5	3	2	60%
6	6	5	2	3	40%
7	7	5	1	4	20%

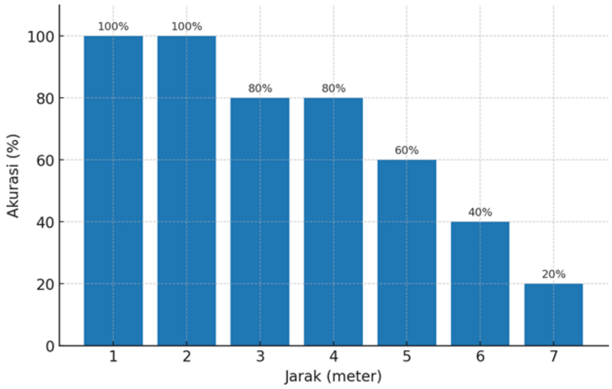

Figure 8. PIR sensor distance vs accuracy graph

3.3 Quality of Service (QoS) Configuration

Configuring Quality of Service (QoS) refers to managing and prioritizing network traffic to ensure optimal performance, particularly for applications that are sensitive to delay such as VoIP, video streaming, or online gaming[28].

3.3.1 Throughput Testing

Throughput testing aims to determine the total number of packets successfully received at the destination within a specific time interval. This value is then divided by the duration of the interval. Throughput is measured in kilobits per second (kbps). According to[29], the formula for calculating throughput is given as:

$$Troughput = \frac{Number\ of\ packet\ received}{Observation\ Time} \quad (1)$$

Table 10. Throughput testing results

No	Time Interval	Packets Received	Throughput (kbps)	Throughput Category
1	1 minute	727	72	Fair
2	3 minutes	2534	91	Good
3	5 minutes	3272	60	Fair
4	7 minutes	4679	70	Fair

3.3.2 Delay Calculation

This test aims to evaluate the time required by the system to transmit data between the RFID tag and the RFID reader. The testing process records the timestamp of each data packet sent and received, then calculates the time difference between packets to determine the delay for each transmission. The collected data are then analyzed to calculate the average delay.According to[29], the delay categories are presented in Table 11.

Table 11. Delay category classification

Category	Delay Value (ms)	Index
Excellent	< 150 ms	4
Good	150–300 ms	3
Fair	300–450 ms	2
Poor	> 450 ms	1

The formula for calculating average delay is expressed as:

$$Avarage\ Delay = \frac{Total\ Delay}{Total\ Packets\ Received} \tag{2}$$

Table 12. Delay testing results

No	Time Interval	Packets Received	Delay (ms)	Delay Category
1	1 min	727	91.28	Excellent
2	3 min	2534	71.68	Excellent
3	5 min	3272	97.94	Excellent
4	7 min	3679	155.80	Good

3.3.3 Jitter Testing

Jitter testing aims to measure the variation in the arrival time of data packets received by the RFID system. Significant variation in packet arrival time can affect the stability of the communication system, which may impact the quality of data received by the server. By measuring jitter, the stability of the connection and data transmission in the RFID system during tag reading and data transfer to the server can be evaluated. According to[29], the jitter categories are presented in Table 13.

Table 13. Jitter category classification

Category	Jitter (ms)	Index
Excellent	0 ms	4
Good	0 – 75 ms	3
Fair	75 – 175 ms	2
Poor	> 225 ms	1

The formula for calculating jitter is expressed as:

$$Jitter = \frac{Total\ Variation\ of\ Delay}{Total\ Packets\ Received} \tag{3}$$

Table 14. Jitter testing results

No	Time Interval	Packets Sent	Jitter (ms)	Jitter Category
1	1 min	727	66.98	Good
2	3 min	2534	71.70	Good
3	5 min	3272	97.91	Good
4	7 min	3679	155.81	Good

3.3.4 Packet Loss Testing

Packet loss testing aims to measure the percentage of data packets lost during transmission. Packet loss may occur due to various factors such as network interference or connectivity issues. This testing helps to evaluate the reliability and stability of the network connection in the system[30]. According to the classification, the packet loss categories are shown in Table 15.

Table 15. Packet loss category classification

Category	Packet Loss (%)	Index
Excellent	0–2 %	4
Good	3–14 %	3
Fair	15–24 %	2
Poor	≥ 25 %	1

The packet loss percentage is calculated as follows:

$$Packet\ Loss\% = \frac{Packets\ Lost}{Packets\ Sent} \times 100 \quad (4)$$

Table 16. Packet loss testing results in data transmission system

No	Time Interval	Packets Sent	Packets Lost	Packet Loss (%)	Packet Loss Category
1	1 min	727	0	0	Excellent
2	3 min	2534	0	0	Excellent
3	5 min	3272	0	0	Excellent
4	7 min	4679	0	0	Excellent

4. CONCLUSION

Based on the experimental results of the PIR sensor at various distances, it can be concluded that the sensor demonstrated excellent accuracy at short ranges, achieving 100% accuracy at a distance of 1 meter. However, the accuracy gradually decreased to 0% at a distance of 7 meters. This indicates that the PIR sensor is most effective within a maximum range of 3 meters. Beyond this distance, the sensor performance declined significantly, which may be attributed to the limited infrared detection range and sensor sensitivity. Therefore, for system implementations requiring reliable motion detection, it is recommended to place the object within a short distance from the PIR sensor to maintain optimal detection performance.

The main findings of this study are summarized as follows:

1. The system successfully detected motion automatically through the PIR sensor. When movement occurred within the monitored area, the PIR sensor transmitted a signal to the Raspberry Pi for processing.
2. The Raspberry Pi was able to process data from the PIR sensor effectively and respond in real time by executing subsequent commands, such as activating the camera, buzzer, or sending an alert message.
3. The integration of the system with WhatsApp Messenger proved to be effective. Notifications were automatically delivered to the user via WhatsApp messages containing incident information and image documentation. This feature enhances home security autonomously and in real time.

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