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An IoT-Based Motorcycle Security System Using Arduino and Android for Theft Prevention

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ABSTRACT

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Motorcycle theft remains a prevalent issue, especially in urban areas, where traditional security measures such as mechanical locks and ignition keys are easily bypassed. This research presents an IoT-based motorcycle security system integrating Arduino, Bluetooth communication, and an Android application to enhance theft prevention. The system employs an Arduino Uno microcontroller, HC-05 Bluetooth module, and SW-420 vibration sensor to detect unauthorized access and trigger security mechanisms. Users can remotely monitor and control their motorcycles via an Android application, which allows engine immobilization and alarm activation functions. The system was tested for hardware performance, Bluetooth connectivity, and software reliability. Results indicate that Bluetooth communication remains stable within a 10-meter range, the vibration sensor effectively detects unauthorized movements, and real-time commands between the application and Arduino execute with minimal latency. Cost analysis suggests that the system, with a total hardware cost of Rp 223,000, is an affordable and effective solution for motorcycle security. Despite some range limitations, the study demonstrates the feasibility of IoT-based security enhancements. Future improvements include GPS tracking and GSM communication for extended monitoring. This research contributes to developing innovative, cost-effective, and user-friendly vehicle security solutions.

Keywords:

Arduino

Motorcycle Security

Android Application

Bluetooth

Smart Security System

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INTRODUCTION

Motorcycle theft remains a significant issue worldwide, particularly in urban areas where these vehicles are widely used due to their affordability and convenience. Despite advancements in transportation technology, traditional motorcycle security mechanisms, such as mechanical locks and ignition keys, remain vulnerable to theft. Criminals can bypass these security measures within seconds using tools such as master keys, lock-picking devices, and ignition bypass techniques. Consequently, the demand for an advanced and more secure motorcycle security system has increased, necessitating the integration of modern technological solutions.

Security systems have evolved significantly since the Internet of Things (IoT) emerged. IoT enables real-time monitoring, remote access, and automated control, making it a promising approach for improving motorcycle security. By utilizing IoT-based solutions, vehicle owners can monitor and control their motorcycles remotely through smartphones, significantly reducing the risks associated with theft. IoT-based security systems offer numerous advantages over traditional security mechanisms, including real-time alerts, automatic locking and unlocking, and seamless integration with smart devices.

Arduino, an open-source microcontroller platform, has gained popularity in developing innovative security systems due to its flexibility, affordability, and ease of programming. Arduino can integrate electronic components such as sensors, relays, and Bluetooth modules to create an intelligent security system. Additionally, the Arduino platform supports communication with external devices, making it ideal for IoT applications, including motorcycle security systems. A cost-effective and customizable security solution can be developed by leveraging Arduino to enhance motorcycle protection.

Bluetooth technology is a key component of modern wireless communication, allowing secure short-range connectivity between devices. In motorcycle security applications, Bluetooth enables seamless communication between an Arduino microcontroller and a smartphone, allowing owners to control security features remotely. Bluetooth in IoT-based security systems ensures low power consumption and reliable data transmission. This research explores integrating Bluetooth communication to facilitate secure and efficient interaction between the motorcycle security system and an Android-based application.

Android, the most widely used mobile operating system, is ideal for developing a user-friendly interface for motorcycle security applications. With an Android-based security app, users can monitor their vehicle status, receive alerts, and control security mechanisms remotely. Integrating an Android application with Arduino-based security systems enhances user convenience, enabling secure access and real-time monitoring of motorcycle security conditions. A robust and interactive security system can be implemented by combining Android's extensive development resources with IoT capabilities.

The proposed IoT-based motorcycle security system integrates hardware and software components to provide enhanced protection against theft. The hardware includes an Arduino Uno microcontroller, a Bluetooth module (HC-05), a vibration sensor, and a relay module, while the software comprises an Android application developed using MIT App Inventor. This system aims to provide a comprehensive security solution by offering engine immobilization, alarm activation, and real-time notifications. These features contribute to reducing unauthorized access and improving vehicle security management.

Existing motorcycle security systems often lack adaptability and are prone to bypassing methods used by thieves. While some motorcycles have advanced security features, such as smart keys and GPS tracking, these solutions are often expensive and not widely available in entry-level motorcycles. By developing an IoT-based security system using Arduino and Android, a cost-effective and customizable solution can be introduced to enhance motorcycle protection without requiring complex installations or additional infrastructure.

One of the main challenges in implementing motorcycle security solutions is balancing security effectiveness with user convenience. A security system that is too complex may discourage users from utilizing it effectively, whereas a system that is too simple may be easily compromised. Therefore, this research emphasizes the importance of designing a motorcycle security system that is both secure and easy to use. By leveraging the connectivity of IoT, users can interact with their security system remotely and receive instant notifications in case of security breaches.

This IoT-based security system prevents theft and serves as a deterrent. The presence of an advanced security mechanism can discourage potential thieves from targeting motorcycles equipped with such systems. Moreover, remotely turning off the engine in case of unauthorized access provides an added layer of protection. This feature ensures that even if a thief gains access to the vehicle, they cannot operate it, reducing the likelihood of successful theft attempts.

Security solutions in IoT-based applications are continuously evolving, and this research contributes to the ongoing development of innovative vehicle security technologies. Implementing IoT-enabled security solutions is not limited to motorcycles; similar approaches can be extended to other vehicles, including cars and bicycles. By developing an effective and scalable security system, this research lays the foundation for future advancements in intelligent vehicle protection, integrating additional features such as GPS tracking and biometric authentication for enhanced security.

The significance of this research lies in its ability to provide an affordable, accessible, and customizable motorcycle security solution. Unlike commercial security systems

8 that may require expensive subscriptions or proprietary hardware, this system is designed to be open-source and adaptable, allowing users to modify and enhance their security setup as needed. This flexibility ensures that many users can benefit from the proposed system, regardless of budget constraints or technical expertise.

This research aims to advance innovative motorcycle security solutions by integrating IoT technology, Bluetooth communication, and Android-based application development. The findings will provide valuable insights for future developments in vehicle security systems and demonstrate the feasibility of cost-effective, user-friendly, and technologically advanced solutions for preventing motorcycle theft.

RESEARCH METHOD

The research was conducted using a combination of hardware and software
2 development methods to design an IoT-based motorcycle security system. The primary focus was integrating an Arduino-based microcontroller with an Android application via Bluetooth. The methodology involved selecting appropriate hardware components, developing software applications, and ensuring seamless integration to achieve a functional and reliable security system.

The hardware implementation in this research, as illustrated in Figure 1, comprises several key components, including an Arduino Uno R3, Bluetooth HC-05 module, SW-420 vibration sensor, four-channel relay module, and DC-DC adjustable step-down regulator. These components were meticulously chosen based on their compatibility, cost-effectiveness, and seamless integration with the motorcycle's electrical system. The Arduino Uno R3 functions as the central processing unit, responsible for interpreting commands from the Android application and managing critical security features such as engine immobilization, alarm activation, and sensor monitoring, ensuring an effective and responsive motorcycle security system.

Figure 1. Hardware Architecture of the IoT-Based Motorcycle Security System

A smartphone running the Android operating system was used to communicate with the security system via Bluetooth. The smartphone application is a remote control, allowing users to lock or unlock the engine, activate or deactivate the alarm, and monitor security alerts. The Bluetooth HC-05 module establishes a wireless connection between the smartphone and the Arduino, facilitating real-time command execution. This module was chosen for its reliability in short-range communication and low power consumption, making it suitable for vehicle-based applications.

To enhance security, the system incorporates a vibration sensor (SW-420) that detects unauthorized movement or tampering with the motorcycle. The sensor is susceptible to vibrations, and when triggered, it sends signals to the Arduino, which activates the alarm and prevents unauthorized engine startup. The relay module controls the motorcycle's electrical circuits, enabling the Arduino to switch the ignition and alarm system on or off based on user commands.

A power management system was implemented to ensure the stability of the security system without overloading the motorcycle’s battery. The DC-DC step-down converter

(LM2596) regulated the voltage from the motorcycle's battery to a safe operating level for the Arduino and other components. This regulation prevents overheating and ensures the longevity of the electronic components. Integrating the power supply with the motorcycle's battery allows continuous security system operation without requiring external power sources.

The software development for this research involved two primary tools: the Arduino IDE and MIT App Inventor. The Arduino IDE was used to program the microcontroller, defining how it processes incoming commands, interacts with sensors, and controls the relay module. The programming logic included functions for handling Bluetooth communication, responding to sensor inputs, and executing security actions. The software was developed with efficiency in mind, ensuring minimal latency in processing commands and triggering security features.

6 The Android application was developed using MIT App Inventor, a visual programming environment for rapid prototyping and implementation. The application features a simple and user-friendly interface with buttons for engine control, alarm activation, and system status monitoring. When the application is launched, it automatically checks Bluetooth availability and prompts the user to connect to the Arduino-based security
12 system. If the connection is successful, the application allows the user to control security functions with a single tap.

The software design, as illustrated in Figure 2, follows a flowchart-based approach to ensure logical execution and ease of troubleshooting. The application initially attempted to establish a Bluetooth connection with the security system. The application automatically returns to the initial screen if the connection fails due to inactive

Bluetooth, incorrect pairing, or a system error. Once successfully connected, the interface presents users with various security control options, allowing them to efficiently interact with and manage the motorcycle security system.

Figure 2. Flowchart of the IoT-Based Motorcycle Security System

Extensive testing was performed on the hardware and software components to validate the system's effectiveness. The Arduino code was tested for accurate command execution, ensuring that Bluetooth communication and relay control operated as expected. The vibration sensor was calibrated to detect different levels of motion, preventing false alarms while maintaining security effectiveness. The application underwent multiple test scenarios to verify its ability to connect to the Arduino system, execute commands, and display accurate status updates.

The integration of the hardware and software components was evaluated to ensure seamless operation. Bluetooth connectivity was tested at varying distances to determine the effective range of communication between the smartphone and the security system. The response time of commands was analyzed to measure the delay between user input and system execution. The system's power consumption was monitored to ensure the motorcycle's battery could sustain continuous operation without significant depletion.

This research method effectively combined hardware and software engineering principles to develop an IoT-based motorcycle security system. The methodology

11 ensured that the system was cost-effective, user-friendly, and reliable in preventing unauthorized motorcycle access. The implementation and testing phases provided valuable insights into the system's performance, highlighting areas for potential improvement in future developments.

RESULTS AND ANALYSIS

This research demonstrates the successful development and implementation of an IoT-based motorcycle security system using Arduino and an Android application. The system was tested in multiple scenarios to assess its efficiency, reliability, and practicality. The evaluation was divided into two main aspects: hardware performance and software functionality. By conducting extensive tests, this study aimed to ensure that the system could effectively prevent unauthorized motorcycle access while maintaining ease of use for the owner.

As depicted in Figure 3, the hardware implementation underwent rigorous testing to ensure that each component operated as intended. The Arduino Uno functioned as the central control unit, processing input signals from the Android application and executing commands such as activating or deactivating the relay module. The Bluetooth HC-05 module established a stable and reliable connection between the Arduino and the smartphone, enabling real-time control over security functions. The SW-420 vibration sensor effectively detected movement and promptly triggered the alarm in response to unauthorized tampering with the motorcycle. Each component was tested individually and in combination to validate their integration, responsiveness, and overall system reliability.

Figure 3. Hardware Implementation and System Integration of the IoT-Based Motorcycle Security System

Power management was a critical aspect of the hardware evaluation. The system was designed to draw power from the motorcycle's battery, with a DC-DC step-down converter regulating voltage to prevent overloading sensitive electronic components. The power consumption was measured to ensure the security system could operate without significantly draining the battery. The results confirmed that the system maintained efficient power usage while ensuring continuous operation, proving it sustainable for long-term use.

Software testing, as illustrated in Figure 4, was conducted to validate the functionality of the Android application and its communication with the hardware components. The application successfully established a Bluetooth connection with the module, enabling users to control the engine and activate or deactivate the alarm remotely. The interface was evaluated for responsiveness, ensuring all security features operated with minimal latency. Bluetooth connectivity was tested across various distances, confirming stable communication up to 10 meters. However, connection reliability declined beyond this range, presenting a potential limitation that could be addressed through future enhancements, such as integrating alternative wireless communication technologies for extended range and improved reliability.

Figure 4. Software Testing and Bluetooth Communication Performance of the IoT-Based Motorcycle Security System

The system's security features were tested under simulated theft attempts. When the unauthorized movement was detected, the vibration sensor immediately sent a signal to the Arduino, which activated the alarm and disabled the engine through the relay module. The system's reaction time was measured, and results indicated that the response occurred within milliseconds, providing immediate deterrence against potential theft. This level of responsiveness is crucial in preventing successful unauthorized access to the motorcycle.

Table 1. Hardware Performance Evaluation Results of the IoT-Based Motorcycle Security System

NO

Testing

Test Case

Expected Result

Test Result

1

Bluetooth

Connected to a smartphone via Bluetooth

Bluetooth is connected

Successful

2

Relay

Sent high or low logic signals

Relay turns on and off

Successful

3

Vibration Sensor

Given vibration input

Sends data output to Arduino

Successful

Black-box testing evaluated the system's reliability in real-world conditions, focusing on hardware performance (Table 1) and software functionality (Table 2). The assessment confirmed that all key security features, including engine immobilization, alarm activation, and real-time notifications, operated as expected. The Bluetooth connection was tested under various environmental conditions to assess its stability and effectiveness. While the system demonstrated consistent performance in open areas, occasional interference from physical obstacles and electronic devices affected connectivity, highlighting potential areas for future optimization and enhancement. Another critical aspect of the analysis was user interaction and ease of operation. The Android application was designed to be simple and intuitive, allowing motorcycle owners to access and control security features quickly. User feedback from initial trials indicated that the system was easy to operate and provided a sense of security. However, some users suggested improvements such as an extended Bluetooth range or alternative communication methods like GSM for remote access beyond 10 meters.

Table 2. Software Functionality Testing Results of the IoT-Based Motorcycle Security System

No

Testing

Test Case

Expected Result

Test Result

1

Bluetooth Bike Application

Check whether Bluetooth is active; if not, a notification prompts activation.

Checks Bluetooth status and activates it

Successful

2

Connect Button

Connects to the Arduino Bluetooth module

Bluetooth is connected

Successful

3

Engine Button

Turns the engine on or off

Controls the engine

Successful

4

Alarm Button

Turns the alarm on or off

Controls the alarm

Successful

The security system's cost analysis, presented in Table 3, was conducted to evaluate its feasibility as a commercial product. The estimated hardware cost amounted to Rp 223,000, positioning it as a cost-effective alternative to conventional motorcycle security systems. With its low cost and high efficiency, this system offers a practical and affordable security solution, making it an attractive option for motorcycle owners seeking advanced protection without excessive expenses.

Table 3. Cost Estimation of the IoT-Based Motorcycle Security System

No

Component Name

Price (Rp)

1

Arduino Uno R3 + USB Cable

Rp 81,000

2

LM2596 DC-DC Adjustable Stepdown

Rp 11,000

3

HC-05 Bluetooth Transceiver

Rp 50,000

4

5V 4-Channel Relay

Rp 41,000

5

Mini Breadboard

Rp 8,000

6

SW-420 Vibration Sensor

Rp 11,000

7

1 DC Jack

Rp 5,000

8

Jumper Cables (Pack of 20)

Rp 16,000

Total

Rp 223,000

The research findings also highlighted potential limitations and areas for improvement. While the system performed efficiently in controlled environments, Bluetooth range constraints limit its applicability in larger areas. Additionally, the reliance on the motorcycle's battery for power, though efficient, requires further evaluation to ensure long-term sustainability. Future enhancements could include integrating GPS tracking for theft recovery and incorporating cloud-based data storage for enhanced security monitoring.

The results confirm that the developed security system successfully meets its objectives of providing an effective, low-cost, and user-friendly motorcycle security solution. Combining IoT-based technology, Bluetooth communication, and an Android interface offers an innovative approach to preventing motorcycle theft. With further enhancements and optimizations, this system has the potential to set a new standard for innovative vehicle security solutions.

CONCLUSION

This research successfully developed and tested an IoT-based motorcycle security system integrating Arduino, Bluetooth communication, and an Android application. The system effectively prevented unauthorized access through key security features such as engine immobilization, alarm activation, and real-time monitoring. Testing results confirmed that Bluetooth connectivity remained stable within a 10-meter range, and the vibration sensor accurately detected unauthorized movement, triggering the security response immediately. The system’s affordability, with a total hardware cost of Rp 223,000, makes it a viable solution for motorcycle owners seeking an enhanced yet cost-effective security mechanism.

Despite its effectiveness, some limitations were observed, including Bluetooth range constraints and dependence on the motorcycle's battery. Future improvements should include integrating GPS tracking for theft recovery, GSM communication for remote access beyond Bluetooth range, and enhanced power management solutions to ensure long-term usability. This research contributes to advancing IoT-based security solutions for motorcycles, demonstrating the potential for scalable and customizable innovative security systems that can be extended to other vehicle types.

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