Post-theft Face Capturing and Remote Controlled Security System on Motorcycle-based IoT Using ESP32

Putut Son Maria[1], M. Ardiansyah[2], Elva Susianti[3]
[1,2] Department of Electrical Engineering, Faculty of Science & Technology, Sultan Syarif Kasim Riau State Islamic University, Pekanbaru, Riau, Indonesia.
[3]Department of Electronic Systems Engineering Technology, Politeknik Caltex Riau, Pekanbaru, Riau, Indonesia.

ABSTRACT
The IoT-based Security System for Motorcycles with Post-Theft Face Recognition and Remote Control Using ESP32 in this study is designed to significantly enhance motorcycle protection by incorporating nearly real-time monitoring, intelligent image capture, and remote control functionalities into a single integrated platform. As motorcycle theft remains a persistent issue in many regions, conventional security measures such as mechanical locks and alarms often prove insufficient. This system addresses those limitations by leveraging Internet of Things (IoT) technology to provide continuous surveillance and immediate response capabilities. One of the key features of the system is its image capture and post-theft face capturing functionality. When suspicious movement, forced ignition, or unauthorized access is detected, the system automatically activates the camera module to capture facial images of the individual involved. These images can then be stored or transmitted to the motorcycle owner and relevant authorities for identification and investigation. This feature helps overcome the common challenge faced by law enforcement officers and vehicle owners who often lack reliable evidence or location data to track stolen motorcycles and identify perpetrators. By integrating the ESP32 microcontroller with the ESP32-CAM camera module, GPS tracking, motion sensors, and wireless communication technologies such as Wi-Fi or GSM, the system ensures seamless data collection and transmission. The GPS module provides real-time location tracking, while remote control capabilities allow the owner to disable the engine or activate alerts through a mobile application. Together, these components create a comprehensive security solution that offers both preventive protection and valuable post-incident investigative support.

***Keywords**: Post Theft, Face capture, IoT.*

Date of Submission: 05-02-2026 Date of acceptance: 22-02-2026

I. INTRODUCTION

Motorcycles are an essential and efficient means of daily transportation for a large portion of the population in Indonesia. Their widespread use is largely due to their affordability and low operating costs, making them the primary mode of transport for many lower- to middle-income communities across the country[1][2]. As a result, the number of motorcycles on the road has grown significantly.

However, this heavy reliance on motorcycles has also increased their vulnerability to theft. Data from 2022 indicate that Riau Province ranked second highest on the island of Sumatra in reported motorcycle theft cases[3]. One of the main challenges in addressing this crime is the limited availability of integrated security features in most motorcycles. Law enforcement authorities and vehicle owners often lack tools to automatically detect or record the location of stolen vehicles, and identifying perpetrators remains difficult. This technological gap makes it harder to track and recover stolen motorcycles, prolonging the impact on both victims and the police.

There are two main approaches to motorcycle security systems: conceptual designs[4] and practical implementations. These approaches typically involve both mechanical and electrical techniques to enhance vehicle protection. These includes manual locking mechanisms[5][6], electrical circuit breakers, fingerprint-based access[7][8], vibration sensors[9][10], SMS notifications[11][12], MAC address filtering, NFC-based systems[13] and IoT[14]. While these innovations are effective as preventive measures, they generally provide limited assistance once a theft has already occurred.

Post-theft recovery can be supported by tracking a vehicle's position using GPS, but identifying the perpetrator is also important for investigation and recovery efforts. Therefore, this study proposes a motorcycle security system that incorporates a feature capable of capturing images of the perpetrator during a theft incident, providing both location information and visual evidence to support post-theft response.

II. RESEARCH METHOD

a. System Block Diagram

Figure 1 shows diagram block of the system in this study. A smartphone running a Telegram Bot, labeled as the "User Gadget" represents the vehicle owner. Through the Telegram app, the user can send commands remotely. An Internet icon indicates that communication happens over an online network. A MiFi module acts as a portable Wi-Fi hotspot which provides internet connectivity since this device is installed inside the motorcycle.

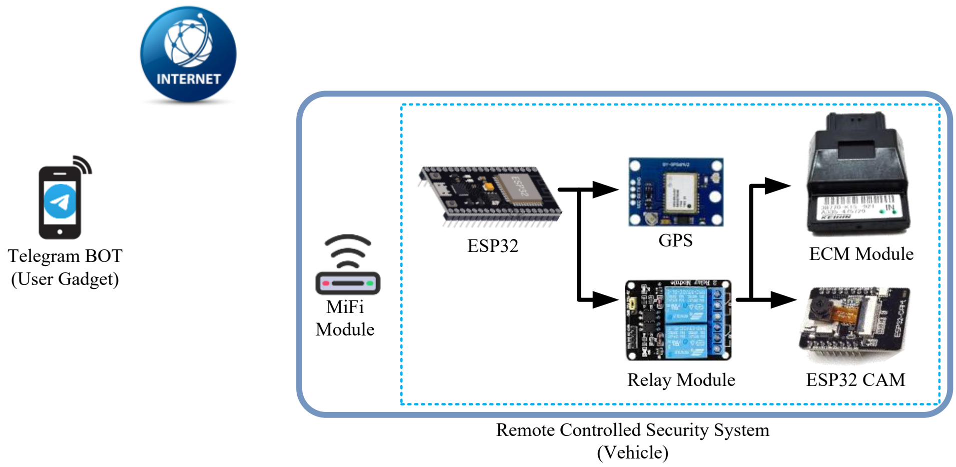

Figure 1. System Block diagram

An ESP32 microcontroller, which acts as the brain of the system, receives commands from the internet via the MiFi module and processes them. A GPS module provides real-time location tracking of the vehicle, and A Relay module, which controls electrical switching operations, such as enabling or disabling vehicle functions. ECM (Engine Control Module) is the factory default engine control unit of the vehicle's engine system. An ESP32-CAM module captures images or live video for monitoring purposes. The ESP32 sends commands to the GPS for location data, activates relays to control vehicle operations, interfaces with the ECM for engine-related control, and communicates with the ESP32-CAM for visual surveillance.

b. Wiring diagram

Figure 2 shows the wiring diagram of the circuit. The motorcycle 12V battery is the main power source. The negative terminal (black) is system ground. The positive terminal (red) feeds into the ignition/key contact. At this point, nothing is powered until the key is turned ON. When the key is turned ON, 12V flows from the battery positive through the key switch. This energizes the main 12V power line of the system then power splits into multiple branches: 1) toward the Step-Down Converter, 2) toward the relay-controlled ECM line and 3) Toward other 12V devices (like ESP32-CAM if directly powered). The 12V from the ignition switch enters the step-down converter. The converter responsible for reducing 12V to a safe logic voltage (typically 5V or 3.3V) and providing stable power for low-voltage electronics. This regulated voltage powers ESP32, Voltage sensor module, GPS module and Relay module (control side). The voltage sensor is powered by the regulated voltage, it Also monitors the battery's 12V line and sends an analog signal (C1/C2 lines) to the ESP32. The purposes are to lets ESP32 measure battery health and detects low voltage or tampering.

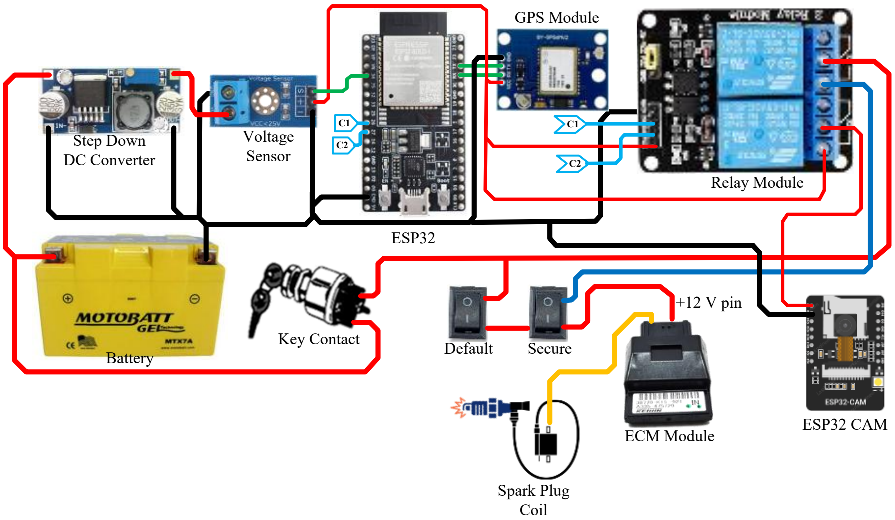

Figure 2. Wiring diagram

Once powered by the step-down converter ESP32 will boot up, initializes GPS, relay control, and monitoring logic. ESP32 will also reads Battery voltage, detect Mode switches (Default / Secure) and access GPS data. The ESP32 does not directly power heavy loads but instead it only sends control signals. GPS is powered by the regulated supply. It responsible for sending location data to ESP32 via serial communication. The relay module is driven by ESP32 and handles 12V to ECM. When ESP32 activates the relay, contact of the relay connects 12V from ignition line to ECM. If ESP32 deactivates relay then the 12V path to ECM is cut and Engine will be disabled. This is the core immobilizer function.

III. RESULTS AND DISCUSSION

a. Hardware

Figure 3 illustrates the complete hardware assembly installed inside a durable black plastic enclosure designed for vehicle applications. The enclosure serves not only as a protective casing but also as insulation against dust, vibration, and minor impacts that may occur during regular motorcycle operation. At the center of the assembly is ESP32 microcontroller the main development board featuring a prominent metal RF shield. This microcontroller functions as the core processing unit of the system, managing communication, sensor input, data processing, and control operations. It is mounted onto a screw-terminal breakout board, allowing multiple wire connections to be secured firmly and organized efficiently. This setup improves reliability and simplifies maintenance or troubleshooting.

Positioned at the top of the enclosure is a blue 2-channel relay module. The relay module is responsible for switching external electrical loads, such as controlling the ignition system or disabling the engine remotely. Several wires are connected to its terminals, they perform its role in managing high-current or high-voltage lines safely through low-power signals from the ESP32.

Also visible is a blue GPS receiver module equipped with a small square antenna and metal shielding. This module communicates with the ESP32 to provide real-time location data. A separate square ceramic patch antenna, connected via a coaxial cable, enhances GPS signal reception for improved accuracy. Additionally, a step-down voltage regulator board, identifiable by its large inductor and capacitors, converts the motorcycle's 12V battery supply into stable 5V or 3.3V outputs required by the electronic components. Overall, the compact and organized layout demonstrates that the system is specifically designed for secure and practical installation within a motorcycle.

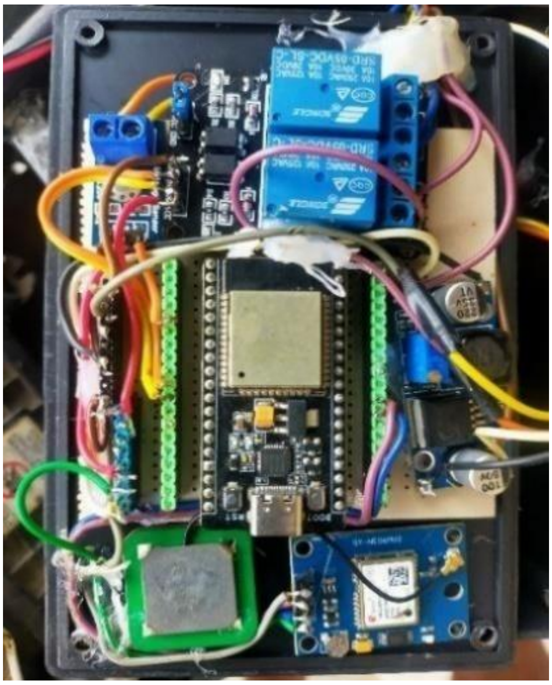

Figure 3. Physical wiring

The motorcycle used for testing he system is a Honda CB150R as shown on Figure 4. When the seat is removed, it is exposing the storage/battery compartment and wiring. Inside the open seat area, a black rectangular is the Controller Box contains the electronics shown earlier (ESP32, relays, GPS, and power circuitry). MiFi Router is placed in the under-seat compartment. This device provides mobile internet connectivity so the system can send data remotely.

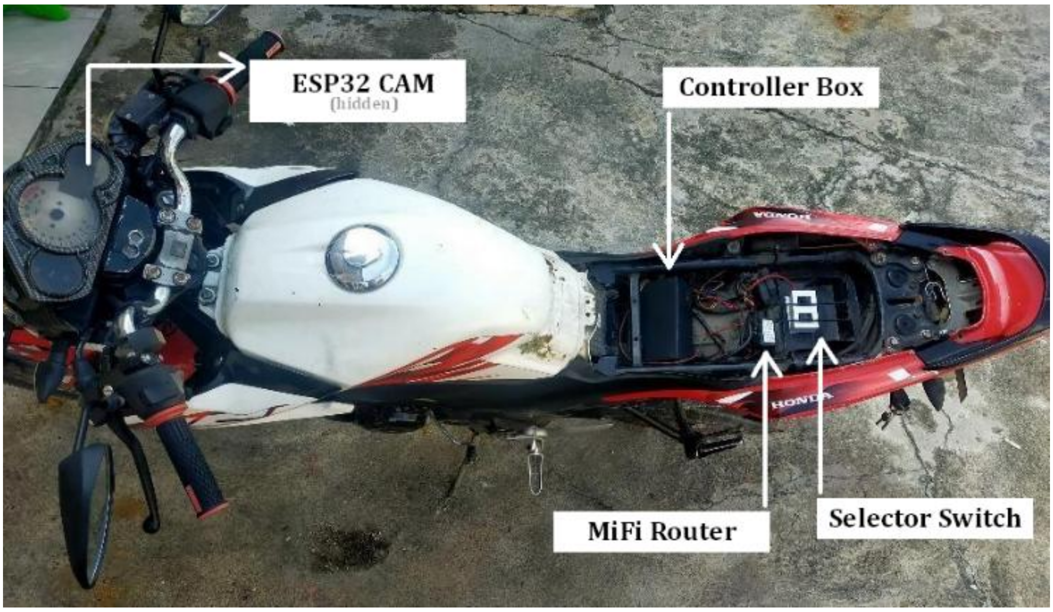

Figure 4. Hardware positioning

Two switches are mounted near the compartment as selector switch mode. These switches are used to change operating modes, such as normal mode versus secure mode. an ESP32 CAM (hidden) is concealed near the instrument cluster or handlebar area, positioned to capture forward-facing video or images. Several wires run between the devices under the seat and toward the front of the motorcycle, indicating connections to power and control lines.

b. Face capture

Figure 5 shows a smartphone screen displaying a conversation with a Telegram bot named "KeamananMotorIoT." The bot has sent a sequence of photos captured by a camera system. Each photo is taken a few moments apart, as indicated by the timestamps around 17:33–17:34 Those photos provided a successful execution of the request and response.

The photo is visible from a low camera angle by a ESP32CAM positioned below or mounted in a fixed location. Across the three images, the person's head position and facial expression change slightly, indicating normal movement while the camera continues taking snapshots.

The bot automatically sends captured images to the user, triggered by motion detection or a request command. This allows the system owner to remotely see what the camera has recorded in near real time. A camera captures images, a controller processes them, and a Telegram bot delivers the results instantly to the user's phone, providing quick visual feedback about activity near the monitored area.

Figure 5. Camera capturing angle

c. Location tracking

There are Four types of command to operate the Security system as shown on Figure 6. The user sends commands such as /HidupkanMotor and /MatikanMotor for turning the motorcycle on and off. The bot will reply with confirmation messages like "Motor dihidupkan" and "Motor dimatikan," indicating that the system successfully executed the requested actions.

Another command, /LokasiMotor, is used to request the motorcycle's location. In response, the bot sends geographic coordinates (latitude and longitude) along with a Google Maps link, allowing the user to view the motorcycle's position on a map. The scene demonstrates how an IoT-based motorcycle security and monitoring system can be controlled remotely. Through the Telegram interface, the user can send commands, receive confirmation of engine status, and obtain real-time location information, providing a convenient way to monitor and manage the vehicle from a distance.

In this study, a series of experiments were conducted at three different locations, as presented in Table 1, in order to evaluate the accuracy and reliability of the GPS tracking component integrated into the system. These test locations were deliberately selected to represent varying environmental conditions, such as trees or buildings and areas with potential signal obstructions, to observe how such factors might influence satellite signal reception and positional accuracy. The objective of conducting trials in multiple locations was to ensure that the GPS module performs consistently and provides dependable data regardless of its surroundings.

Table 1 presents a detailed comparison of geographic coordinate measurements obtained from the Neo-6M GPS module and those recorded using Google Maps as a reference standard. Specifically, the table lists the latitude (garis lintang) and longitude (garis bujur) values generated by the Neo-6M module and compares them with the corresponding coordinates displayed on Google Maps for the same physical locations. In addition, the table includes the calculated difference (selisih) between the two sets of coordinates. This difference represents the positional discrepancy or margin of error between the GPS module's readings and the reference measurements.

Figure 6. Location request command

By analyzing these differences, the study assesses the level of precision achieved by the Neo-6M GPS module. A smaller selisih value indicates higher positional accuracy and better system performance, while larger discrepancies may suggest signal interference, satellite limitations, or environmental factors affecting measurement reliability.

Table 1. Location of roadtest

No	Lokasi	Garis Lintang		Garis Bujur		
		Neo-6M	*Google Maps*	Neo-6M	*Google Maps*	Selisih
1	Jl. Karya	0.457665	0.457731	101.374362	101.374541	18.64
2	UIN Suska Riau	0.466279	0.466463	101.356363	101.356479	22.90
3	Jl. Taman karya	0.460134	0.460008	101.376625	101.376539	15.51

Three locations are included in the comparison: Jl. Karya, UIN Suska Riau, and Jl. Taman Karya. For each site, the latitude and longitude recorded by the Neo-6M module are very close to those provided by Google Maps, indicating that the GPS module is capable of determining positions with reasonable accuracy as shown on Figure 7. The differences shown in the final column range from approximately 15.51 to 22.90 meters, suggesting that the Neo-6M readings deviate from the reference coordinates by only a few tens of meters.

Overall, the table demonstrates that the Neo-6M GPS module provides location data that is generally consistent with Google Maps, with small positional differences that are typical for standard GPS receivers operating without advanced correction techniques. This level of accuracy is sufficient for applications such as vehicle tracking, monitoring, or basic navigation.

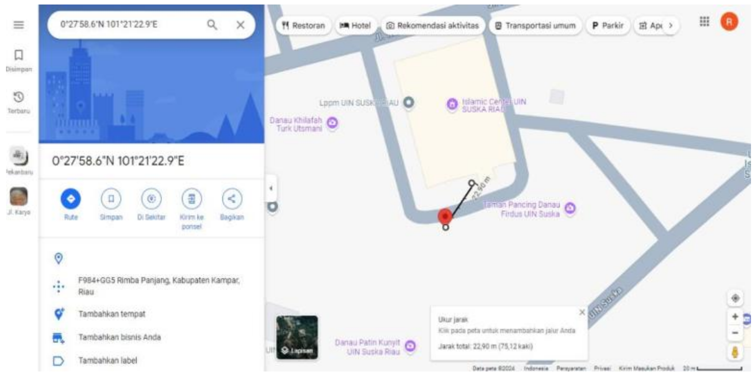

Figure 7. Actual position compared to Google map

d. Battery voltage

The installation of an ESP32 in a battery-powered system makes it important to consider the current drawn from the battery, because even relatively small continuous currents can significantly affect battery life over time. The ESP32, along with supporting components such as sensors, GPS modules, relays, and communication devices, consumes power not only during active operation but also in idle or standby modes.

Figure 8 shows the relationship between battery voltage (Tegangan Baterai) and time (Waktu, in hours) over a 20-hour period. The horizontal axis represents time in hours, while the vertical axis shows the battery voltage in volts (V). At the starting point (0 hours), the battery voltage is approximately 15 volts, indicating a fully charged or recently charged condition. As time progresses, the voltage gradually decreases. After 4 hours, the voltage drops to around 13.5 volts, showing a noticeable initial decline. By 8 hours, the voltage further decreases to approximately 12.8 volts, and continues to decline steadily to about 12.1 volts at 12 hours.

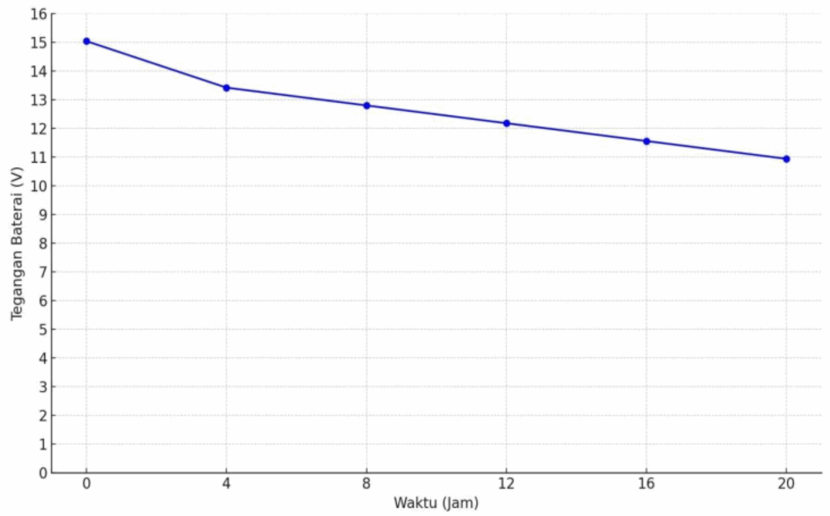

Figure 8. Battery discharge

The downward trend continues beyond 12 hours, with the voltage reaching roughly 11.5 volts at 16 hours and finally around 11 volts at 20 hours. The slope of the graph indicates a consistent and gradual discharge pattern rather than a sudden drop, suggesting a stable load or continuous power consumption over time. The graphic demonstrates the normal discharge behavior of a battery under use. The steady decline in voltage over the 20-hour period indicates ongoing energy consumption, and by the end of the observation period, the battery voltage approaches a level that may be considered low for reliable operation in many 12V systems. Experimental results show that the minimum battery voltage required to start the engine is 11.5 volts, while the minimum voltage needed to operate the security device is 10.5 volts. Therefore, when the motorcycle is not in use, it should be started at least every 16 hours to recharge the battery and maintain sufficient voltage.

The security system designed in this study relies on two key conditions: a stable electrical power supply from the battery and the presence of a communication network signal. If the power line to the ESP32 is interrupted, the system will be unable to function. Likewise, if the GPS module is unable to obtain a cellular signal, any images captured of the perpetrator cannot be sent to the user.

IV. CONCLUSION

The Post-theft Face Capturing and Remote Controlled Security System on Motorcycle-based IoT Using ESP32 is designed to improve motorcycle security through real-time monitoring, image capture, and remote control. The system uses an ESP32, an ESP32-CAM, a GPS module, and wireless communication to detect suspicious activity and capture images after unauthorized access or theft attempts. The captured images and location data are sent to the vehicle owner through a Telegram bot, allowing the owner to monitor the motorcycle remotely. The system also provides remote control features, such as checking the motorcycle's status and disabling the engine, enabling a quick response to theft. This security system depends on two main factors: a stable power supply from the battery and a reliable communication network. If the ESP32 loses power, the system cannot operate, and if there is no cellular signal, the captured images cannot be transmitted to the user.

REFERENCES

[1] I. P. S. Indah, A.-K. Al-Khowarizmi, P. P. H. MD, A. Perdana, and A. A. Manurung, "Implementation And Design of Security System On Motorcycle Vehicles Using Raspberry Pi3-Based GPS Tracker And Facedetection," *Sinkron*, vol. 8, no. 3, pp. 2003–2007, 2023.

[2] R. Ikhwan and C. Dewi, "Motorcycle security system based on Internet of Things (IoT)," *J. Ind. Autom. Electr. Eng.*, vol. 01, no. 01, pp. 164–171, 2024.

[3] M. Darusman, A. O. Putri, and L. P. Pratama, "Implementation of Motorcycle Security System Using Fingerprint R503," *J. Glob. Eng. Res. Sci.*, vol. 2, no. 2, pp. 79–85, 2023.

[4] M. Muhajirin, Taufik, and M. Arafah, "Sistem Keamanan Penguncian Sepeda Motor Dengan Autentikasi Wifi Smartphone," *Jtriste*, vol. 12, no. 1, pp. 76–85, 2025.

[5] A. Rakhmadi, D. K. Aji, S. Rosad, A. Azis, and R. Wahyusari, "An IoT-Based Motorcycle Security System Using Arduino and Android for Theft Prevention," *Compiler*, vol. 14, no. 1, p. 43, 2025.

[6] A. Shahkutty, A. B. Sujan, R. Abhay, A. S. M. N, and N. Afran, "Anti Theft System for Motorcycle Using Bluetooth," vol. 12, no. 4, pp. 196–203, 2024.

[7] B. S. R. T. Bryan, "Rancang Bangun Sistem Keamanan Sepeda Motor Menggunakan Fingerprint Berbasis Arduino," *J. CoSciTech (Computer Sci. Inf. Technol.*, vol. 5, no. 1, pp. 119–125, 2024.

[8] R. Muzawi, Y. Efendi, U. Rio, and D. Toresa, "Security System For Motorcycle Using Raspberry Pi and Fingerprint With Mobile-Based Finite State Machine (FSM) Method," *Innov. Res. Informatics*, vol. 5, no. 1, pp. 14–21, 2023.

[9] E. Elisa, P. Alpianita, N. Syam, and F. Farida, "Prototype Security Alarm System on Motor Vehicles," *J. Inform. Multimedia, Infomation*, vol. 2, no. 1, pp. 1–13, 2024.

[10] R. B. Fernandez, D. Theodore, and R. Seroje, "Two-Way Motorcycle Authentication with Alerting and Tracking System Using Mobile Application," *Int. Res. J. Adv. Eng. Sci.*, vol. 7, no. 3, pp. 246–255, 2022.

[11] A. Prasetio and W. S. Aji, "Motorized Vehicle Security System Using SMS with GPS Tracking Method Based on Arduino UNO Citation Document," *Bul. Ilm. Sarj. Tek. Elektro*, vol. 3, no. 1, pp. xx–xx, 2021.

[12] K. Purwanto, Iswanto, T. K. Hariadi, and M. Y. Muhtar, "Microcontroller-based RFID, GSM and GPS for motorcycle security system," *Int. J. Adv. Comput. Sci. Appl.*, vol. 10, no. 3, pp. 447–451, 2019.

[13] A. S. Firdaos, "Sistem Pengamanan dan Pemantau Sepeda Motor Menggunakan NFC (Near Field Communication) dan GPS (Global Positioning System) Security and Monitoring System in Motorcycle Using NFC (Near Field Communication) and GPS (Global Positioning System)," *Telekontran*, vol. 5, no. 1, 2017.

[14] G. P. Insany, S. A. Alawiyah, Somantri, D. R. Septian, and Iyusmani, "Implementation of IOT-based Motorcycle Security System with Cut Off Engine and Mobile Application," *bit-Tech*, vol. 8, no. 1, pp. 1080–1088, 2025.