IJAIT (International Journal of Applied Information Technology)

http://journals.telkomuniversity.ac.id/ijait/

Implementation of A Motorcycle Vehicle Security System with Arduino-Based Fingerprint, Global Positioning System and Short Message Service Gateway

Randi Rizal [a, d], Aso Sudiarjo [b], Nur Widiyasono [a, *], Dede Rizal Nur Samsi [c], Muhammad Faiz [b]

[a] *Dept. of Informatic, Siliwangi University, Indonesia*
[b] *Dept. of Informatic, Perjuangan University, Indonesia*
[c] *Dept. of Information System, Cipasung University, Indonesia*
[d] *Faculty of Information and Communication Technology, UTeM, Malaysia*

randirizal@unsil.ac.id, asosudiarjo@unper.ac.id, nur.widiyasono@unsil.ac.id, dederizalnursamsi@uncip.ac.id, mfaiz@unper.ac.id

ARTICLE INFO

Received July 24th, 2023
Revised August 22nd, 2023
Accepted September 7th, 2023
Available online Dec. 9th, 2025

Keywords;
Arduino, fingerprint, GSM module, GPS module, security system, motorcycle.

ABSTRACT

The increase in demand for motorized vehicles, especially motorcycles, from 2016 - 2021 has recorded an increase of 5.03% per year. Along with the increasing number of people using motorbikes as their main means of transportation, there is a growth in motorcycle theft. One cause of the increase in these cases is that the motorcycle security system still relies on the lock system. So, it is necessary to improve security with unique modern keys that can only be accessed by specific people, one of which is a security system using biometric technology. This research has combined motorcycle security systems using fingerprint, GSM and GPS modules based on Arduino Uno. The results of testing the fingerprint module scanning time obtained an average scanning time of 1.04 seconds. Testing the SIM800L GSM module obtained an average processing time of receiving SMS and sending back a response to a registered number, which is 9.32 seconds and the results of testing the accuracy of data retrieval between the U-blox Neo-6m GPS module and GPS on the Oppo A3S brand smartphone, with the calculation of the average difference distance of 0.75 Meters. Motorcycle vehicle security was successfully implemented by utilizing the fingerprint module, GPS module and GSM module as an intermediary in the form of SMS between the user and the microcontroller so that it functions as layered security.

Acknowledgment

Thanks to the Department of Informatics, Faculty of Engineering, Siliwangi University, Cipasung University and Perjuangan University for collaborating and providing the opportunity to implement the result of this research.

* Corresponding author at:
Department of Informatics, Faculty of Engineering, Siliwangi University
Jl. Siliwangi No. 24 Kahuripan, Kec. Tawang, Kota Tasikmalaya, 46115
Jawa Barat – Indonesia
E-mail address: nur.widiyasono@unsil.ac.id

ORCID ID:
- First Author: 0000-0002-4377-2137
- Second Author: 0000-0001-5317-8521
- Third Author: 0000-0003-3048-4467

http://dx.doi.org/10.25124/ijait.v8i2.6354
Paper_reg_number IJAIT000080202 2024

1. Introduction

Motorcycles are the most widely used transportation in Indonesia [1]. The reasons for this phenomenon are the affordability, flexibility, and efficiency in using the motorcycle, with the use of more efficient fuel and a smaller size compared to cars [2], [3]. Based on data from the Indonesian National Police, the demand for motorized vehicles, especially motorcycles, in 2016 to 2021 recorded a 5.03% annual increase. This increase is due to the increasing population [4]. Along with the increasing number of people using motorbikes as their main means of transportation, there is a growth in motorcycle theft. In March 2021, the West Java Regional Police held the Jalan Lodaya Operation 2021 and succeeded in securing 322 motorcycle vehicles from motorcycle theft suspects [5]. The increase in these cases could be due to the motorcycle security system that still relies on the lock system [6], so that perpetrators of motorcycle vehicle theft can freely carry out their actions [7]. So, it is necessary to increase security with modern unique keys that can only be accessed by specific people, one of which is a security system using biometric technology [8]. The use of biometrics makes it possible to increase security because it requires verification of the unique characteristics of the user, one of which is the use of registered fingerprints to gain access [9].

Solutions to deal with this problem have been carried out in several previous studies. For example, in research [10], the motorcycle security system uses an Arduino Nano-based password that allows turning on the ignition and utilizing the password as a motorcycle security tool to open access to start the motorcycle engine. This system is also equipped with a function to turn off the alarm with a trial distance of 7 meters. The development of a motorcycle vehicle security system uses a fingerprint module with Arduino Uno as the controller is carried out in [11], [12] and a motorcycle security system using Arduino-based Radio Frequency Identification (RFID) is addressed in [13]. In addition, the design of a security system on motorbikes uses a Microcontroller-based Short Message Service (SMS) Gateway and utilises the Global Positioning System (GPS) to track locations with a vulnerability of 3 to 4 seconds is discussed in [14]. Developing a security system for two-wheeled vehicles using SMS that can determine the position and movement of the vehicle is done in [15].

In this research, the development of a motorcycle security system is carried out by combining the results of previous research, namely combining Arduino-based Fingerprint, Global System Mobile (GSM), and GPS modules as an increase in layered security. Fingerprint-based system is an efficient and secure biometric technology because it provides a strong, reliable, and easy-to-use personal identification for user authentication as security protection and theft [16]. The Global Positioning System (GPS) system is used to track the vehicle's position using a global navigation satellite system and can be visualized using Google Earth [17]. The GSM module is also used for remote system mobilization by sending SMS commands and receiving location [18].

2. Related Work

Research [10] creates a system to turn on the ignition and use a password as a motorcycle security tool to open access to start the motorcycle engine according to what has been programmed. This motorcycle security system is also equipped with an infrared remote to turn off the alarm at a trial distance of 7 meters. However, this study still uses a key to turn on the electricity on the motorbike. In [12], the system uses a Fingerprint module to turn on the vehicle and Arduino Uno as the controller. The system is considered relatively secure. However, it needs to add a GSM module to anticipate theft and a GPS module to track the coordinates of the motorbike's location. Research [13] successfully tested the reading distance of the Card / Tag by the RFID reader ranging from 1 to 3.5 cm. If the ID code on the RFID card does not match the ID, the vehicle starter system cannot be turned on and start the buzzer.

In addition, research [14] uses fingerprints to turn on the machine as well as using the SMS gateway from the GSM module and tracking the location with it. However, it is still necessary to design tools that do not take up too large dimensions, and the GSM module could be improved to turn off the motorbike engine when theft occurs. Another study conducted by [15] succeeded in making a two-wheeled vehicle security system using SMS to determine the position and movement of the vehicle. However, it is necessary to combine the system with a fingerprint-based key security system. In research [19], the motorcycle system runs well using Arduino Uno and fingerprint sensors, so only registered fingerprints can turn the motorcycle on and off. However, it is necessary to add a GSM module and maximize the use of GPS to detect vehicle location changes and send this information via an SMS gateway.

The design of an Arduino-based motorcycle security system using fingerprints, GPS and SMS gateways is the focus of this research. The main objective of this research is to implement the development of an Arduino-based motorcycle vehicle security system by applying efficient and safe biometric technology [20], [21], using the GPS module to detect the movement of the vehicle's position as well as tracking the vehicle's position [11], [16], [17] and the GSM module as remote mobilization by sending commands and receiving locations [18].

3. System Design

The design of a motorcycle vehicle security system with Arduino-based fingerprints, GPS and SMS gateways is based on a flowchart as shown in Figure 1.

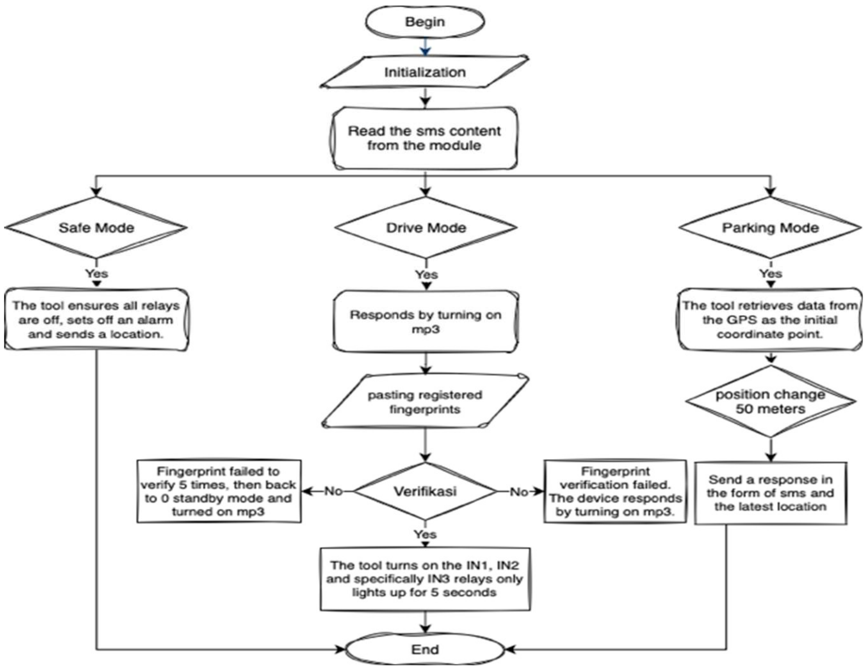

Figure 1 System Flowchart

The designed system flowchart is the first step in making a motorcycle vehicle security system using fingerprints, GPS, and SMS gateways. The most important part in a system is to make the system into three major parts, namely Input, Process and Output.

The Input of the security system is the SMS which only registered numbers have full access to the security system. Each SMS command received by the GSM module will be processed via the microcontroller according to the command received. For the "Mode Drive" command, the microcontroller will activate the fingerprint scanner module where only registered fingerprints can turn on or off the relay connected to electricity and the motorcycle starter. If there is a failure during the fingerprint validation process, the DF player mini will automatically turn on. When validation fails five times, the microcontroller will return to standby mode and turn on the DF player mini module.

On the "Parking Mode" command, the microcontroller will turn on the DF player mini and retrieve coordinates data from the GPS module as a reference for further sending information about the GPS module via the GSM module. If the GPS module detects a movement of more than a radius of 50 meters, the microcontroller will send the latest coordinates via the GSM module to the registered number in the form of an SMS. On the "Safe Mode" command, the microcontroller will set off an alarm on the DF player mini module and retrieve the latest location data from the GPS module to ensure all relays are off, then send the data to registered numbers via the GSM module in the form of SMS.

The hardware design of this motorcycle security system and the module configuration can be seen in Table 1 and Figure 2.

Table 1 Configuration of Using Arduino-Nano Pins

Arduino Nano Pin #	Fingerprint Pin	GSM SIM 800L Pin	GPS Neo6m v2 Pin	Df mini player Pin	Relay	Speaker	Step down	Nodemcu
D2	TX	-	-	-	-	-	-	-
D3	RX	-	-	-	-	-	-	-
D4	-	-	-	TX	-	-	-	-
D5	-	-	-	RX	-	-	-	-
-	-	-	TX	-	-	-	-	D1
-	-	-	RX	-	-	-	-	D2
D8	-	TX	-	-	-	-	-	-
D9	-	RX	-	-	-	-	-	-
D10	-	-	-	-	IN1	-	-	-
D11	-	-	-	-	IN2	-	-	-
D12	-	-	-	-	IN3	-	-	-
5V	-	VCC	-	VCC	VCC	-	-	-
3,3V	VCC	-	VCC	-	-	-	-	3,3V
GND	GND	GND	-	GND	GND	-	-	-
-	-	-	GND	-	-	-	-	GND
-	-	-	-	SPK1	-	(-)	-	-
-	-	-	-	SPK2	-	(+)	-	-
VIN	-	-	-	-	-	-	(+) *Out*	-
GND	-	-	-	-	-	-	(-) *Out*	-
RX0	-	-	-	-	-	-	-	TX

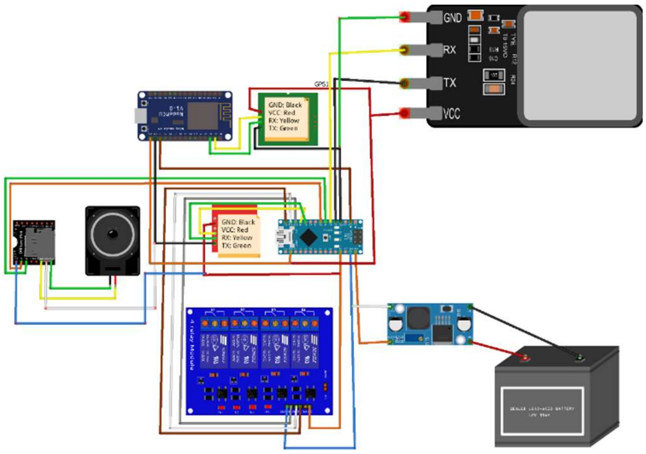

Figure 2 Schematic Wiring or Cabling

4. Result and Analysis

This part consists of 2 stages, namely the implementation and the testing of modules of the entire function to ensure that all parts work according to design and to find functional errors in the system. The design implementation is shown in Figure 3 and Figure 4.

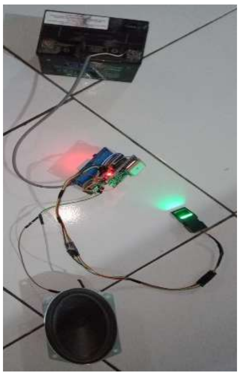

Figure 3 Results of The Implementation of System Design

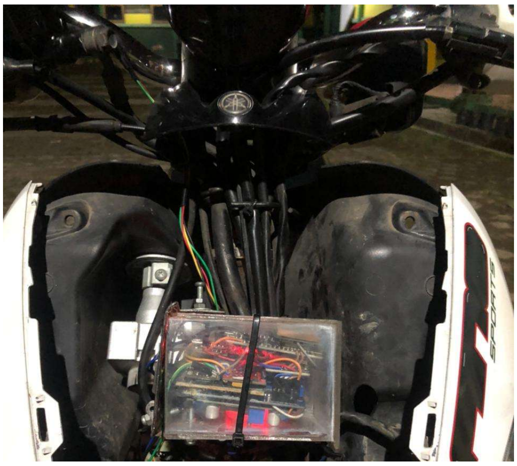

Figure 4 Implementation of Tools on Motorcycle Vehicles

Furthermore, the testing phase is carried out for each module to ensure the tool can work properly and can be analyzed. Coding on the Arduino IDE is done by inputting it into the microcontroller to do the testing and observing it through the IDE serial monitor.

1. Fingerprint Sensor Testing. Fingerprint sensor testing is carried out to ensure whether the sensor is detected by the microcontroller module and can work properly, especially when scanning registered fingerprints. The testing measured the scanning time using a stopwatch on a smartphone for different finger conditions. A fragment of code for the microcontroller module and sensor testing on the Arduino IDE can be seen in Table 2.

Table 2 Code Microcontroller Module and Sensor Testing

Code for microcontroller module and sensor testing

```
#include <Adafruit_Fingerprint.h>
SoftwareSerial mySerial(2, 3);
Adafruit_Fingerprint finger = Adafruit_Fingerprint(&mySerial);
void setup ()
{
 Serial.begin(9600);
 while (!Serial);
 delay(100);
 Serial.println("finger detect test");
 // set the data rate for the sensor serial port
 finger.begin(57600);
 delay (5);
 if (finger.verifyPassword()) {
  Serial.println("Found fingerprint sensor!");
 } else {
  Serial.println("Did not find fingerprint sensor :(");
  while (1) { delay(1) ;  }
 }
 finger.getTemplateCount();
 if (finger.templateCount == 0) {
     Serial.print("Sensor contains "); Serial.print(finger.templateCount); Serial.println("
templates");
Serial.print("Waiting for valid finger…");
}
```

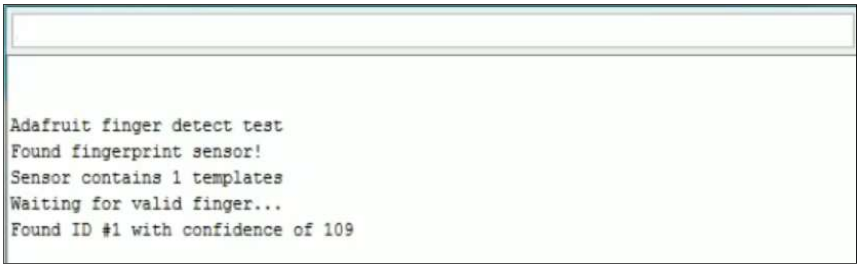

Figure 5 Detect and Verify Fingerprint Sensors

Based on Figure 5, the fingerprint sensor has been detected by the microcontroller module, which indicates that the fingerprint sensor can work properly. Next, a finger scanning time test was carried out on five registered fingerprints with different finger conditions. The test results can be seen in Table 3.

Table 3 Fingerprint Test Result

No.	Hand	Registered Finger	Condition	Response Result	Scan Time (seconds)
1	Right	Thumb	Normal	Valid	0.97
2			Wet	Not Valid	1.03
3			Dirty	Not Valid	1.00
4		Index Finger	Normal	Valid	1.12
5			Wet	Not Valid	0.95
6			Dirty	Not Valid	1.19
7		Middle Finger	Normal	Valid	1.10
8			Wet	Not Valid	0.92
9			Dirty	Not Valid	1.10
10	Kiri	Thumb	Normal	Valid	0.91

No.	Hand	Registered Finger	Condition	Response Result	Scan Time (seconds)
11			Wet	Not Valid	1.14
12			Dirty	Not Valid	0.94
13		Index Finger	Normal	Valid	1.01
14		Index Finger	Wet	Not Valid	1.12
15		Index Finger	Dirty	Not Valid	0.97
Average					1.04

The results of testing the fingerprint scanning time can be seen in Table 3, and they show that the average time for the AS608 sensor to scan registered fingerprints under normal, wet, and dirty conditions is 1.04 seconds.

2. SIM800L GSM Modul Testing. GSM module testing is carried out to ensure that the module is detected by the microcontroller and receives a good signal. A fragment of code for the microcontroller module and sensor testing on the Arduino IDE can be seen in Table 4.

Table 4 Code for SIM800L GSM Module testing

Code for module GSM testing

```
Inisialisasi GSM
*/
gsm.println("AT\r");
updateGSM();
gsm.println("AT+CPIN=?\r");
updateGSM();
gsm.println("AT+CMGDA=6\r");
updateGSM();
gsm.println("AT+CMGF=1\r");
updateGSM();
gsm.println("AT+CNMI=1,2,0,0,0\r");
updateGSM();
```

Figure 6 Detect and Access the GSM Module

IDE monitor serial observation results in Figure 6, which shows that the microcontroller can detect and access the GSM module. After that, the test is carried out by sending an SMS command using a Telkomsel provider, with a specified distance and calculating the time for the receiving process until it sends a response back to the registered number using a stopwatch. The test results can be seen in Table 5.

Table 5 Modul GSM SIM800L Testing Result

No	Testing	Distance (Meter)	Response Time (Second)
1	Testing 1	1	8.96
2	Testing 2	10	9.22
3	Testing 3	20	9.24
4	Testing 4	30	10.27
5	Testing 5	40	9.16
6	Testing 6	50	9.06

No	Testing	Distance (Meter)	Response Time (Second)
7	Testing 7	60	9.58
8	Testing 8	70	9.57
9	Testing 9	80	9.17
10	Testing 10	90	8.86
11	Testing 11	100	9.42
Average			9.32

Based on the test results in Table 5, the average time needed for the SIM800L GSM module to receive SMS and send back a response to a registered number in 1 to 100 meters is 9.32 seconds.

3. Testing of the U-blox Neo-6m GPS Module. GPS module testing is carried out to ensure that the module is detected by the microcontroller module and can receive coordinate data properly. Coding is done on the Arduino IDE to be sent to the microcontroller module, which can be seen below.

Table 6 Code for GPS Module Testing

Code for GPS module testing

```
Void loop () {
If (Serial.available{}) {
        //gsm.write(Serial.read()};
        String dataGPS = Serial.readString();
        dataGPS.trim();
        dataGPS.replace("\n","");
        dataGPS.replace("\r","");
        int index – dataGPS.indexOf("%";

        latitude = dataGPS.substring(0,index) .toFloat();
        longitude = dataGPS.subtring(index +1, dataGPS.length()).toFloat();

        Serial.print("Latitude:"); Serial.print(latitude, 6);
        Serial.print("Latitude:"); Serial.println(longlatitude, 6);
}
```

The test is carried out by locating the GPS module indoors and outdoors to determine the possibility of the GPS module being connected to the satellite. The test results are shown in Table 7.

Table 7 Test Results of U-blox Neo-6m GPS Module

No	Testing Place	Condition	Information	Result
1	*Indoor*	Home	Experiment 1	Not Connected
2			Experiment 2	Not Connected
3			Experiment 3	Not Connected
4		Garage	Experiment 1	Not Connected
5			Experiment 2	Not Connected
6			Experiment 3	Not Connected
7		Basement	Experiment 1	Not Connected
8			Experiment 2	Not Connected
9			Experiment 3	Not Connected
10	*Outdoor*	Roofed Parking	Experiment 1	Connected
11			Experiment 2	Connected
12			Experiment 3	Connected
13		Open Parking	Experiment 1	Connected
14			Experiment 2	Connected
15			Experiment 3	Connected
16		Shady Tree Streets	Experiment 1	Connected
17			Experiment 2	Connected

No	Testing Place	Condition	Information	Result
18			Experiment 3	Connected
19		Open Streets	Experiment 1	Connected
20			Experiment 2	Connected
21			Experiment 3	Connected

Based on the test results in Table 7, the GPS module can connect to satellites when it is placed outdoors but it is difficult to connect to them otherwise. Furthermore, in the testing to measure accuracy of taking coordinates, the result values from reading the coordinates of the U-blox Neo-6m GPS module are the latitude and longitude of it. Then, the difference in the distance is calculated with the GPS reading results from the Oppo A3S brand smartphone using measure distance on Google Maps and the calculation of the Euclidian distance. The following test results are shown in Table 8.

Table 8 The Results Modul GPS U-blox Neo-6m

No	Modul GPS		Google Maps		Range A (M)	Range B (M)	Deviation (M)
	Lat	Long	Lat	Long			
1	-7.370285	108.236340	-7.370267	108.236311	3.79	2.52	1.27
2	-7.370273	108.236300	-7.370267	108.236271	3.29	3.10	0.19
3	-7.371665	108.235630	-7.371671	108.235472	17.60	16.75	0.85
4	-7.371707	108.235630	-7.371648	108.235494	16.50	15.90	0.60
5	-7.370070	108.231180	-7.370044	108.231211	4.50	3.09	1.41
6	-7.370075	108.231180	-7.370042	108.231222	5.94	5.77	0.17
Average							0.75

Based on the test results in Table 5, it shows that the accuracy of data collection between the U-blox Neo-6m GPS module and GPS on the Oppo A3S smartphone has an average distance difference of 0.75 meters, with the calculation using the Euclidean distance as follows.

Euclidean distance formula:

$$d = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} * 111.319$$

Explanation:

x1 : Latitude of the GPS module
x2 : Longitude from Google Maps
y1 : Latitude of the GPS module
y2 : Longitude from Google Maps

The formula estimates the distance between two points on Earth's surface using their latitude and longitude coordinates, providing a straightforward method to calculate proximity. Here, x1 and x2 represent the longitudes, and y1 and y2 represent the latitudes of the two points. The Euclidean distance calculated gives the distance in degrees, and multiplying by 111.319 converts this distance into kilometres, as each degree of latitude or longitude corresponds approximately to 111.319 kilometres. This method is a simple approximation, particularly suitable for short distances; however, for more accurate measurements over longer distances, especially on a curved surface, the Haversine formula is generally preferred due to its higher precision. Distance A: Euclidean distance calculation results. Distance B: Google's Measure distance calculation results Maps 111.319 km: grade 1° (scale) earth.

$$d = \sqrt{((-7.370285)^2 - (-7.3702676)^2)} * 111.319$$
$$d = \sqrt{(-1.8x10^{-5})^2 + (2.9x10^{-5})^2} * 111.319$$
$$d = \sqrt{(\frac{-18}{100000})^2 + (\frac{29}{100000})^2} * 111.319$$
$$d = \sqrt{(\frac{324}{10000000000})^2 + (\frac{841}{10000000000})^2} * 111.319$$
$$d = \sqrt{\frac{11165}{10000000000}} * 111.319$$
$$d = \sqrt{0.0000000011165} * 111.319$$
$$d = 0.000034132096 * 111.319$$
$$d = 0.0037995508\ km$$
$$d = 3.7995508\ meter$$

Comprehensive testing of the entire system is conducted to ensure it functions correctly, identifying and addressing any functional errors or issues. This process is crucial for validating the system's reliability and effectiveness, as detailed in Table 9, Table 10, and Table 11. These tables illustrate the various test scenarios and outcomes, ensuring that all components work seamlessly together and meet the required specifications, thereby minimizing potential operational failures and ensuring optimal performance.

Table 9 Drive Mode Test Result

Input Data	Expected	Observation	Conclusion
Send a message in the form of the command "Mode Drive" to the number installed on the GSM module	The microcontroller receives the message then responds by running mp3 and activating the fingerprint scanner.	As expected,	Succeed
Pasting registered fingerprints	The fingerprint scanner detects registered fingerprints, if they match, the microcontroller will activate IN1, IN2 and specifically IN3 for only 5 seconds.	As expected,	Succeed
Pasting unregistered fingerprints	The fingerprint scanner detects fingerprints if it is not detected then the microcontroller will respond by turning on the mp3.	As expected,	Succeed
Pasted an unregistered fingerprint more than 5 times	The microcontroller will respond by turning on the mp3 and making sure all the relays are off.	As expected,	Succeed

Table 10 Safe Mode Test Results

Input Data	Expected	Observation	Conclusion
Send messages in the form of commands Safe Mode to the number installed on the GSM module	The microcontroller receives the message then ensures a relay is off, sends a response based on the current vehicle location and turns on the mp3.	As expected,	Succeed

Table 11 The Results Parking Modes

Input Data	Expected	Observation	Conclusion
Sends a message in the form of the command "Parking Mode" to the number installed on the GSM module.	The microcontroller receives a message confirming a relay is off and sends a response.	As expected,	Succeed
The GPS module detects a location shift of more than 50M	The microcontroller sends responses based on the current vehicle location.	As expected,	Succeed

5. Conclusions

The development of a motorcycle vehicle security system was successfully achieved by utilizing the fingerprint module to increase the security because only registered fingerprints are used to ignite and start the motorcycle engine, while the

GSM module acts as an intermediary in the form of SMS between the user and the microcontroller so that it functions as layered security. This study also uses the GPS module to track the position of the vehicle when the vehicle is stolen by detecting the movement of the motor coordinates when it exceeds a radius of approximately 50 meters from the starting point when parked and sending this information via SMS Gateway. The results of testing the scanning time of the fingerprint module using a stopwatch on smartphones with different finger conditions obtained an average scanning time of 1.04 seconds. After testing the GSM SIM800L module, the average processing time to receive an SMS and send a response back to a registered number within 1 to 100 meters is 9.32 seconds. The accuracy testing of data retrieval between the U-blox Neo-6m GPS module and GPS on the Oppo A3S brand smartphone, with the calculation results of an average distance difference of 0.75 meters. A more in-depth study is needed for further research because in this study, the fingerprint module could not scan fingerprints in wet and dirty conditions, it was not accompanied by a handlebar lock and the GPS module could only connect to satellites when placed outdoors. In addition, it is necessary to develop an application-based security system incorporated with the tool.

Bibliography

[1] Statista, "Leading modes of transportation among people in Indonesia," *Statista*, Oct. 18, 2022.

[2] R. Rizkyana and A. Surya, "Sistem Keamanan Sepeda Motor Dengan Mengganti Saklar Starter Menggunakan Fingerprint," *JTTM: Jurnal Terapan Teknik Mesin*, vol. 2, no. 1, pp. 43–51, 2021.

[3] Risdiyanto, A. Munawar, M. Z. Irawan, and A. A. Nugraha, "Model selection of online motorcycle taxi and motorcycle modes on work trips," *IOP Conf Ser Mater Sci Eng*, vol. 1007, no. 1, p. 012059, Dec. 2020, doi: 10.1088/1757-899X/1007/1/012059.

[4] Badan Pusat Statistik, *Statistik Transportasi Darat 2019*. BPS RI, 2020.

[5] R. Perdana, "Polda Jabar Amankan 342 Kendaraan Hasil Curanmor, Cek ke Polres Siapa Tahu Ada Kendaraan Anda," *PRFMNEWS*, 2021. https://prfmnews.pikiran-rakyat.com/jawa-barat/pr-131534598/polda-jabar-amankan-342-kendaraan-hasil-curanmor-cek-ke-polres-siapa-tahu-ada-kendaraan-anda (accessed Dec. 17, 2021).

[6] P. Sihombing, I. S. Daulay, S. Efendy, and I. Syarif, "Motor Vehicle Security using Microcontroller, GPS and Android as Innovation to Prevent Motor Thieves," *J Phys Conf Ser*, vol. 1566, no. 1, p. 012026, Jun. 2020, doi: 10.1088/1742-6596/1566/1/012026.

[7] F. Mahardika, A. Saepullah, M. Z. N. Fuadi, and I. Darmawan, "Penerapan Metode Waterfall pada Skema Sistem Pengaman Sepeda Motor dengan Arduino Nano," *Respati*, vol. 16, no. 2, pp. 63–70, 2021.

[8] M. Kaushal and S. Pathare, "*Advanced Biometric Vehicle Security System*," *Int J Sci Eng Res*, vol. 11, no. 3, 2020, [Online]. Available: http://www.ijser.org

[9] K. Gupta, "*Review Paper on Biometric Authentication*," *International Journal of Engineering Research & Technology (IJERT)*, vol. 5, no. 27, pp. 1–2, 2017, [Online]. Available: https://www.ieee.org/about/technologies/emerging/biometric

[10] D. I. Prasetya and M. Mushlihudin, "Sistem Keamanan Sepeda Motor Menggunakan Kata Sandi Berbasis Arduino Nano," *Jurnal Ilmiah Teknik Elektro Komputer dan Informatika*, vol. 4, no. 1, p. 11, 2018, doi: 10.26555/jiteki.v4i1.8985.

[11] Kiran C S, "Anti-theft Fingerprint Security System for Motorcycles Using Arduino UNO, GPS/GSM Module," *Indian J Sci Technol*, vol. 12, no. 42, pp. 1–5, Nov. 2019, doi: 10.17485/ijst/2019/v12i42/145823.

[12] R. Tullah, N. Nurmaesah, and T. C. Agami, "Sistem Cerdas Keamanan Kendaraan Sepeda Motor Dengan Fingerprint Berbasis Mirkrokontroler," in *Seminar Nasional APTIKOM (SEMNASTIK) 2019*, 2019, pp. 37–44.

[13] M. Ridha Fauzi, "Rancang Bangun Pengaman Sepeda Motor Menggunakan RFID Berbasis Arduino," *Jurnal Surya Teknika*, vol. 7, no. 2, pp. 164–171, 2020, doi: 10.37859/jst.v7i2.2384.

[14] F. N. A. Wijaya, S. Noertjahjono, and Y. A. Pranoto, "Rancang Bangun Sistem Keamanan pada Sepeda Motor Menggunakan SMS Gateway Berbasis Mikrokontroller," *JATI (Jurnal Mahasiswa Teknik Informatika)*, vol. 4, no. 2, pp. 113–119, 2020.

[15] E. Nasrullah, S. Sumadi, A. Ulya Darajat, and F. Lukman Hadi, "Pembuatan Sistem Keamanan Kendaraan Roda Dua Menggunakan SMS," *ELECTRICIAN–Jurnal Rekayasa dan Teknologi Elektro*, vol. 15, no. 3, pp. 209–216, 2021.

[16] N. Kiruthiga and L. Latha, "*A Study of Biometric Approach for Vehicle Security System Using Fingerprint Recognition*," *International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)*,2014.

[17] N. Kiruthiga, L. Latha, and S. Thangasamy, "*Real time biometrics based vehicle security system with GPS and GSM technology*," in *Procedia Computer Science*, 2015, vol. 47, no. C, pp. 471–479. doi: 10.1016/j.procs.2015.03.231.

[18] A. Bukola, "*Development of an Anti-Theft Vehicle Security System using GPS and GSM Technology with Biometric Authentication*," 2020. [Online]. Available: www.ijisrt.com

[19] A. H. Pratama, D. Hartama, M. R. Lubis, I. Gunawan, and I. Irawan, "Sistem Keamanan Sepeda Motor Berbasis Mikrokontroler Menggunakan Aarduino dan Sensor Fingerprint," *Jurnal Penelitian Inovatif*, vol. 1, no. 2, pp. 66–74, 2021.

[20] F. Hidayanti, F. Rahmah, and A. Wiryawan, "Design of Motorcycle Security System with Fingerprint Sensor using Arduino Uno Microcontroller," *International Journal of Advanced Science and Technology*, vol. 29, no. 5, pp. 4374–4391, 2020.

[21] E. A. Z. Hamidi, M. R. Effendi, E. Mulyana, and R. Mardiati, "Implementation security system using motorcycle fingerprint identification and notification Telegram," *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 21, no. 1, pp. 88–96, Feb. 2023, doi: 10.12928/TELKOMNIKA.v21i1.24250.