Low-Cost Vehicle Security System Using Location Change and Vehicle Status Based on Internet of Things

Mas Aly Afandi[1*], Sevia Indah Purnama[1], Gunawan Wibisono[1]

[1]Institut Teknologi Telkom Purwokerto, Banyumas, Indonesia

Article Info

Article history:
Received Sep 12, 2023
Revised Apr 12, 2024
Accepted May 03, 2024

Keywords:
Vehicle security; low-cost system; location change; theft detection

Abstract

Motor vehicle theft is a crime that can potentially harm the owner of the vehicle. This crime should be anticipated, and a security system should be implemented to avoid vehicle theft. Research about vehicle security systems has run into an uptrend. Previous research has already developed security system devices for vehicles with many peripherals. This study aims to develop a new low-cost vehicle security device with location change calculation to cut unused peripherals. The proposed device has a logic checker, horn controller, and vehicle controller as security systems. According to the testing result, the device can detect the vehicle status from off to on while the security system is active. The device will turn on the horn and turn the vehicle off. This function always works at 100%. This device also detects theft according to the location change. This feature works at a 100% rate, with an average error reading location of 4,83m and an average error distance calculation of 0,91m. This distance is tolerable because the owner can still see the vehicle. This research result proves that the device can be used to secure the vehicle. This device's performance will increase if placed outside the building. The data was also successfully sent to the IoT platform without data loss or incomplete data. Compared with other research, the proposed device has fewer peripherals with the same or more security features.

****Corresponding Author:***
Email: aly@ittelkom-pwt.ac.id

INTRODUCTION

Motor vehicle theft is a serious crime in Indonesia. According to the Badan Pusat Statistik (BPS), motor vehicle theft cases in East Java in 2019, 2020, and 2021 were 2.356, 1.429, and 2.249 respectively [1]. Motor vehicle theft can occur more often in the future. This is due to the very lenient punishment for motor vehicle thieves [2]. There are many ways to reduce the theft of motor vehicles committed by society. Generally, people will report to the police. This solution can make the stolen vehicle back to the owner [3]. This condition can happen if the stolen vehicle is not sold. Motor vehicle thieves can be teenagers or adults. The goal of motor vehicle theft is to earn money [4].

This research aims to develop a low-cost device for motor vehicle private security. Many technologies can be used to develop this device. The most promising technology to develop motor vehicle device security is an embedded system with Internet of Things technology. The Internet of Things technology has already been implemented in sectors such as flood mitigation [5], monitoring dust conditions in a warehouse [6], monitoring and controlling a fish farm [7] [8], and smart agriculture [9]. The Internet of Things is a technology providing communication through the Internet. The advantage of this technology is a wide range of communication. This technology can be used to track motor vehicles while thieves steal them. This technology is an integrated system with sensors and actuators. Many research concerns to development of motor vehicle private security. That research proposes several technologies and concepts to develop vehicle private security.

Several technological developments to improve security on vehicles such as face detection [10], radio frequency identification (RFID) [11], internet of things [12], and short messaging services (SMS) gateway [13][14]. That research successfully improves vehicle security. The Internet of Things is the most promising technology for vehicle security. Internet of Things technology can be made by applying a global system for mobile communication (GSM) [15]. Integrating a global positioning system (GPS) to track vehicles, RFID to identify owners, and sending the data to the internet is more secure compared with the security system current times [16][17]. The important part of building a security system is GPS [18]. Many previous studies have focused mainly on security by using multiple sensors and complicated mechanisms. The security system needs to be improved by reducing sensors and components. This improvement will reduce the production cost and more affordable.

This research aims to develop a high-performance low-cost vehicle security with minimal components. The idea is to utilize GPS to detect the distance difference from the vehicle. This device integrates with the vehicle itself and the theft detection system. The device will turn on the horn in the vehicle while the key box on the vehicle changes from off to on in secure mode. The device also turns on the horn while the vehicle moves to another space. The system will be prohibited from turning on if the theft detection is triggered. Sensor data and the suspicious activity on key box vehicles will be recorded in a database using the internet. The proposed device provides minimum hardware, minimum cost production, with enough protection for the vehicle. This research uses different techniques and approaches to develop vehicle security devices.

METHODS

This research uses an experiment, trial and error method with a prototyping model. The goal of this method is a new prototype for vehicle security devices.

Research methods are shown in Figure 1. The first step in this research is identifying system requirements and providing them, especially in hardware requirements. The second step is identifying and providing software requirements. This research uses Arduino IDE for embedding programs into the microcontroller. The third step is designing the program with several logic and scenarios. Program design will be made referring to the design. After the device build consists of hardware and software, the next step is testing.

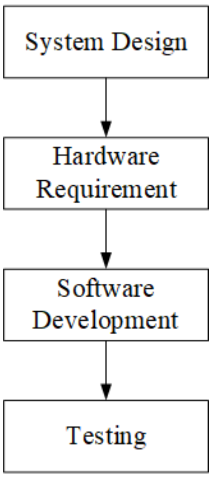

Figure 1. Research Method Block Diagram

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

If the testing result shows any error logic, then rebuild the software. If the testing shows the proposed device follows the scenario without any error logic, then the device is ready to operate with real testing. According to Figure 1, testing will be done after the device is created successfully.

System Design

The proposed device uses GPS as a single sensor for a theft detection system, a Subscriber Identity Module (SIM) for sending data to the cloud, a relay for controlling vehicles, and a microcontroller for the main controller.

Figure 2 shows a block diagram system consisting of hardware requirements. This research uses GPS Neo 6M to detect vehicle movement while the security system is turned on. If the distance is far away from the initial value after the security system is activated then it is possibly moved by the thief. The logic checker consists of a relay to check vehicle conditions after the security system is activated. If electricity flows after the security system is activated then it is possibly done by the thief. The suspicious activity from GPS or logic checker will be determined by the microcontroller.

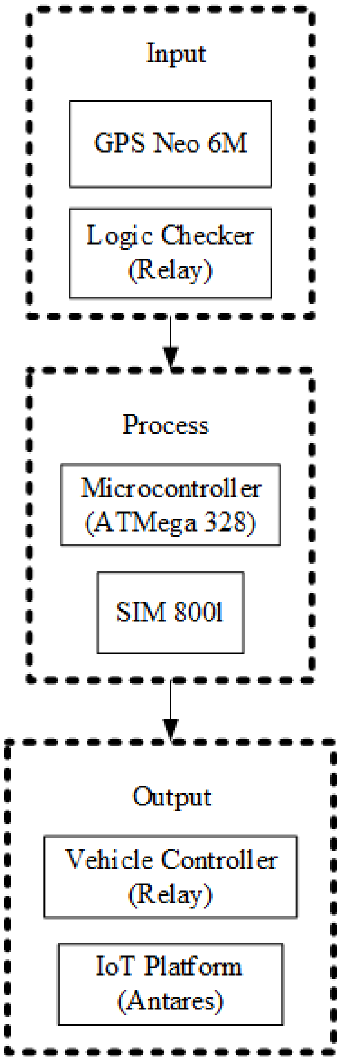

Figure 2. System Block Diagram

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

According to Figure 2, the system only has 5 hardware peripherals hardware. There is the microcontroller, GPS, SIM, Logic checker, and vehicle controller. This peripheral is less than the peripheral needed in another research.

Hardware Requirement

The proposed device needs specific hardware requirements. This research uses ATMega 328 as the microcontroller. Vehicle conditions will be recorded on the IoT platform. ATMega 328 is a microcontroller that already has minimum requirements. The proposed device needs the ability to connect to the internet. This research uses SIM 800l with GSM connectivity to send data to the IoT platform. The SIM 800l is more suitable compared with wide fidelity (WiFi) technology according to the requirement. Vehicle location will be tracked through GPS Neo 6M. The output from GPS Neo 6M is longitude and latitude data. This proposed device aims to use minimal components to simplify security devices. Hardware requirement needs only 2 sensors and 2 actuators controller.

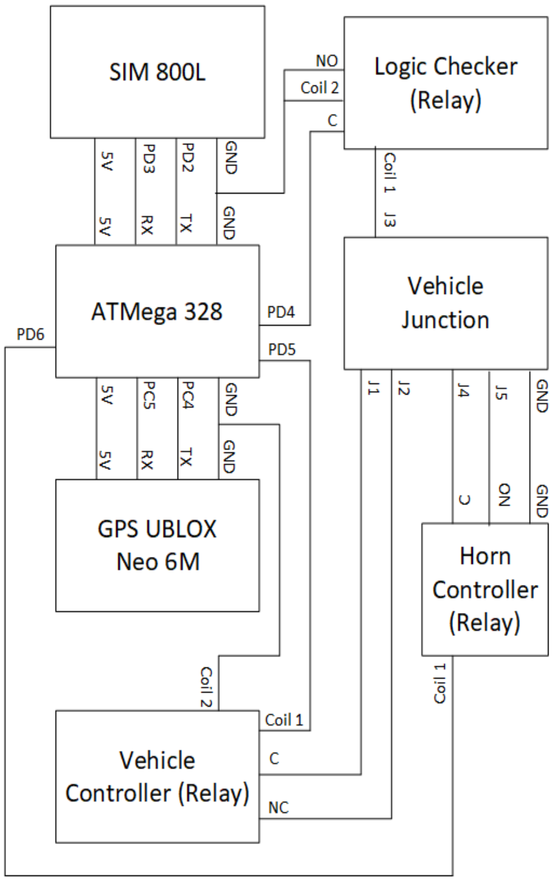

Figure 3. Circuit Block Diagram

Figure 3 shows the block diagram circuit for designing the vehicle security system hardware. GPS communication with pin PC4 and PC5 microcontroller ATMega 328. SIM 800l communication with pin PD2 and PD3 microcontroller ATMega 328. A vehicle junction is a junction connected to motorcycle peripherals. It will connect the horn, key status, and electrical in the motorcycle. J1 and J2 connect with the junction for turning off the motorcycle. If PD5 gives a high signal then the motorcycle will turn off. J3 is the connection to check the motorcycle status from the key connection. If the motorcycle is tuning on then the junction from the key is connected and triggered the relay. The triggered relay will give a low signal from the normally off relay (NO) to the common relay (C) J4 and J5 is a junction for controlling the motorcycle horn. This relay turns on the horn while PD6 gives a high signal.

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

Table 1. Connection Configuration

ATMega 328	Peripherals
PC4	Tx (GPS Neo 6M)
PC5	Rx (GPS Neo 6M)
PD2	Tx (SIM 800l)
PD3	Rx (SIM 800l)
PD4	Logic Checker Relay
PD5	Vehicle Controller Relay
PD6	Vehicle Horn Controller Relay

Table 1. shows the pin configuration through microcontroller ATMega 328 with other peripherals. The SIM 800l and GPS Neo 6M communicate with universal asynchronous receive transmit (UART) communication protocol. It needs to transmit and receive in a microcontroller pin. This research uses software serial to make microcontroller digital pins to receive and transmit pins. This research configures PD2 as a receive pin and connects with a SIM 800l transmit pin. The PD3 pin is configured as a transmit pin and connects with the SIM 800l receive pin. This research configures PC4 as a receive pin and connects with a GPS Neo 6M transmit pin. The PC5 pin is configured as a transmit pin and connects with the GPS Neo 6M receive pin. The logic checker is configured as input. Motor vehicle electricity works at 12V voltage while turned on. To detect this case, the microcontroller needs a relay. If the relay is active, then the relay will connect the 5V line to the input microcontroller. The PD4 microcontroller pin is set as input for this case. The vehicle controller is a relay for connecting the 12V line to the vehicle horn. In this case, the microcontroller pin needs to be configured as output. The PD5 microcontroller pin is configured as an output to trigger the relay.

Software Design

The proposed device also needs software. The software will be embedded in the microcontroller. Software design will explain how the software in the microcontroller works.

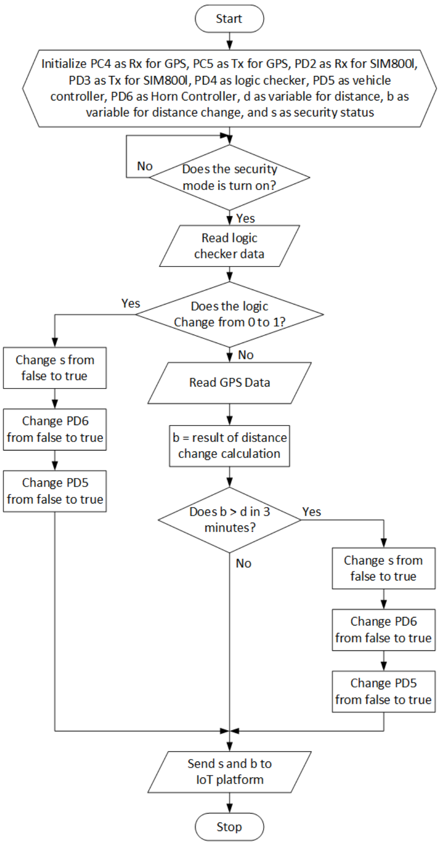

Figure 4. Software Design

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

According to Figure 4, the first instruction is initialization. The initialization follows the hardware connection in Table 1. Initialization also contains several variables such as d for distance information, b for distance change information, and s for vehicle status. The second instruction is to check the security system mode. Users need to turn on the security mode. If the user does not activate the security system, then the proposed device will be idle. If the security system is already activated then the system will be checking the logic checker. The vehicle is supposed to be turned off while the security system is turned on. If the electricity in the vehicle is active then it can be done by the thief. The device will change the vehicle status from false to true indicating that the vehicle is turned on. The device also turns on the horn by sending a high signal to PD6 and turns off the vehicle by sending the high signal to PD5. All the current status will be sent to IoT Platform Antares through SIM 800l as the recording data. Vehicle theft can be done by not turning on the vehicle itself. It can be done by bringing the vehicle using a car. This scenario can be detected by using GPS sensors. The GPS will read the longitude and latitude data from the vehicle and send it to the microcontroller. The microcontroller will be calculating location change by using the haversine formula.

The Haversine formula was introduced by Prof. James Inman in 1835 for measuring distance in aeronautical applications. The haversine formula was used for calculating a distance between 2 points in a spherical shape.

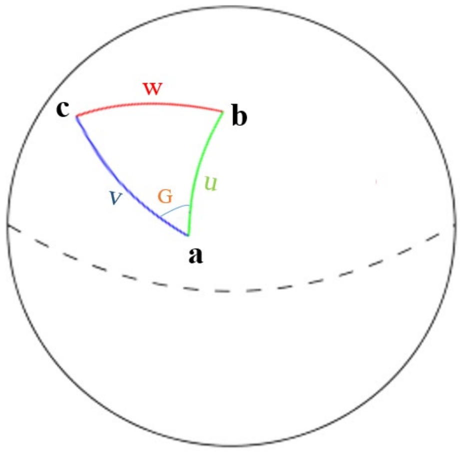

Figure 5. Haversine in Spherical Surface

The Haversine formula, which is shown in Figure 5 will be explained in this part. In Figure 4, a "triangle" on the surface of a sphere is described in a ball unit as three points on the ball marked by a, b, and c. Using the notation, the lengths from a to c are denoted by v, b to a is denoted by u, and c to b is denoted by w. Corner G is the opposite angle from a.

$$\theta = \frac{d}{r} \quad (1)$$

$$hav(w) = hav(u - v) \quad (2)$$

The primary angle is denoted by between v and u. The distance d in Formula 1 is similar to w in Figure 3. The proposed device will be calculated d in a certain time to detect theft activity. This research uses the Haversine formula to calculate d. Since the output from GPS from a proposed device is longitude and latitude in decimal the formula becomes.

$$d = r\ archav(hav(\frac{1-coscos(\theta)}{2}) \quad (3)$$

$$A = hav(Ia_2 - Ia_1) \quad (4)$$

$$B = hav(Ia_2 - Ia_1) \quad (5)$$

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

$$C = (1 - B - B) \quad (6)$$

$$D = 2r\ arcsin \quad (7)$$

$$d = D\left(\sqrt{A - C\ hav(Io_2 - Io_1)}\right) \quad (8)$$

$$E = sin^2\left(\frac{Ia_2 - Ia_1}{2}\right) \quad (9)$$

$$F = sin^2\left(\frac{Io_2 - Io_1}{2}\right) \quad (10)$$

$$d = D\left(\sqrt{E + (1 - E - E).D}\right) \quad (11)$$

$$d = D\left(\sqrt{E + cos(Ia_1).cos(Ia_2).D}\right) \quad (12)$$

The final formula to calculate d with longitude and latitude information in decimal is represented in Formula 12. The initial latitude is denoted by Ia_1, the initial longitude is denoted by Io_1, the latitude change is denoted by Ia_2, and the longitude change denoted by Io_2. The final formula will be computed for the proposed device for calculating the vehicle movement in a certain time. If the location change is too far, then the vehicle might be stolen. The distance in the software is represented by the d variable. The value of the d variable will be decided according to the research data. If this scenario happens, then the device will send the vehicle status, turn on the horn, and turn off the vehicle functionality. This method also can be used in many sectors such as healthcare [19][20], tourism [21], small medium enterprises [22], and education [23][24][25].

Testing

This research will prove the proposed device's performance after the testing process. The testing consists of GPS testing, haversine testing, controller testing, and system testing. GPS testing is especially collecting the GPS data from the device and comparing it with the standard GPS device. This testing will give the information on the difference reading from GPS Neo 6M and standard device. The GPS from the proposed device will be stated to work well if the difference is lower than 10m. This research uses 10m as the error threshold because in 10m the vehicle owner still can see the vehicle. This testing collects 15 data and analyzes it by calculating the range from minimum and maximum data with the standard deviation. The second test is the haversine formula. This test will concern obtaining distance data calculated with the haversine method and online platform. This research uses Google Earth for the comparison of measuring data change. The test will be state work well if the error reading is not greater than 5m. The value of 5m is decided according to the human ability to run. This experiment also analyzes with range of minimum and maximum data with the standard deviation. The total maximum error from the proposed device is 15m from GPS error and haversine formula error. The next testing is controller testing. This test is used to obtain the system performance for controlling the vehicle. This test has been done by collecting 30 data every 1-hour data change. The final testing is overall testing. This test has been done by applying all the theft scenarios until data is sent to the IoT platform. This test is important to make sure the proposed device will work as the concept. This test collects 15 data from two different scenarios. This testing is used to check the algorithm from Figure 4. The algorithm needs to be tested to make sure the hardware and software are working.

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

RESULT AND DISCUSSION

Research tests and experiments will be discussed in this section. Several tests need to be done to obtain the proposed device performance. The first test compares GPS Neo 6M with standard GPS reference.

Table 2. GPS Data Comparison with GPS Reference

GPS Sensor		GPS Reference		D (m)
Long	**Lat**	**Long**	**Lat**	
-7.39122	109.2441	-7.39122	109.2441	4.40
-7.42778	109.2331	-7.42778	109.2331	0.25
-7.42520	109.2307	-7.42521	109.2307	9.63
-7.42403	109.2296	-7.42405	109.2296	3.33
-7.42393	109.2296	-7.42392	109.2296	1.16
-7.43382	109.2391	-7.43386	109.2391	7.88
-7.43110	109.2379	-7.43110	109.2379	0.79
-7.42787	109.2361	-7.42788	109.2361	3.46
-7.42407	109.2351	-7.42402	109.2350	6.01
-7.42051	109.2363	-7.42054	109.2363	3.21
-7.36396	109.2384	-7.36393	109.2385	6.02
-7.41214	109.2381	-7.41213	109.2381	1.61
-7.35056	109.2363	-7.35064	109.2364	9.75
-7.37310	109.2396	-7.37312	109.2397	7.92
-7.38222	109.2418	-7.38219	109.2419	7.09

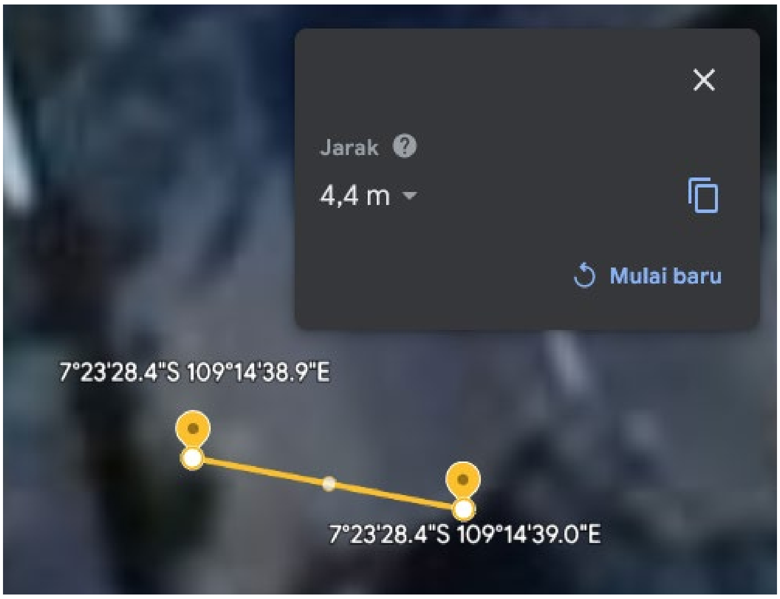

Figure 6. Sample Image of Comparison Output from Data 1 in Table 2

The comparison between GPS from the proposed device and GPS in a mobile phone is shown in Table 2. Figure 6 shows the image sample from Data 1 in Table 2 on how to get D values. This information is obtained by using the google earth platform. Table 2 indicates that the GPS from the proposed device has a difference while pointing motorcycle location shown on D. The discrepancy ranges from 0,25 meters to 9,75 meters, with an average of 4,83 meters and a standard deviation is 3,19. This information points out that even in areas with few barriers, the motorcycle can still be seen. This data proves that the GPS in the proposed device may be inaccurate, but the motorcycle can still be found in a specific condition.

In the second experiment, the difference in location at a specific time is calculated using the Haversine method. The motorcycle will be considered stolen if the motorcycle moves far from its starting point. This experiment uses the same data as Table 1 but with a different source for the D value. The D value in Table 2 is taken from an online platform. The distance must be calculated using the Haversine method because the proposed device is unable to access the internet platform. This test has been done to give the Harvesine method performance compared with the online platform.

Table 3. Harvesine Method Performance Compared with Online Platform

No	Online Platform (m)	Haversine Formula (m)	Deviation (m)
1	4.40	4.34	0.06
2	0.25	0.00	0.25
3	9.63	9.70	0.07
4	3.33	2.65	0.68
5	1.16	1.19	0.03
6	7.88	6.92	0.96
7	0.79	0.78	0.01
8	3.46	3.45	0.01
9	6.01	3.82	2.19
10	3.21	1.07	2.14
11	6.02	5.22	0.80
12	1.61	1.00	0.61
13	9.75	5.12	4.63
14	7.92	7.60	0.32
15	7.09	6.14	0.95

The comparison between the distance from the online platform and the Haversine formula is shown in Table 3. There is a deviation in calculating the distance between the online platform and the haversine formula. The minimum deviation value from Table 3 is 0,01m and the maximum value is 4,63m. The average deviation is 0,91m with 1,24 standard deviations. This data shows haversine formula can be used to calculate the change of vehicle location. The calculation has an error compared with the google earth platform. This error was caused by different methods between Google Earth and Haversine formulas. The proposed device uses a haversine formula because of the limitation of the system. The system cannot access google earth and needs to calculate location changes. This error can be treated as an error tolerance for the proposed device.

The logic checker in the proposed device consists of a relay. This relay is used to check the vehicle's status. The Logic checker performance needs to be tested. The logic should be high if the vehicle is turned on and low if the vehicle is turned off. The horn controller in the proposed device is the actuator to controls the horn in the vehicle. If the horn controller gives a high signal, the horn in the vehicle should be ringing. If the horn controller gives a low signal, then the horn in the vehicle should be turned off. The vehicle controller is a relay to control the vehicle's status. This component is important to turn off if the vehicle is stolen by the thief. If the vehicle controller gives a high signal, then the vehicle cannot be turned on. If the vehicle's actual status is turned on, then it should be turned off while the vehicle controller gives a high value. If the vehicle controller gives a low signal, then the vehicle back to its normal status. The vehicle can be turned on or turned off using the key.

The logic checker, horn controller, and vehicle controller are tested in the third experiment. In this experiment, the proposed device will be tested to turn on and turn off the vehicle horn. The vehicle horn should act as the given signal. This experiment also tests the proposed device to turn off the vehicle while the vehicle is turned on. This experiment is used while the vehicle is stolen and used by theft. The owner can turn off the vehicle and turn on the horn to give the suspicious signal to other people. This experiment also tests the logic checker to make sure the logic checker gives the right signal. The result of this experiment is to get data for the performance of actuators.

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

Table 4. Controller Testing Result

No	LC	VS	HC	HS	VC
1	1	1	1	1	0
2	1	1	0	0	0
3	0	0	0	0	1
4	0	0	1	1	1
5	0	0	1	1	0
6	0	0	1	1	0
7	1	1	0	0	0
8	1	1	0	0	0
9	1	1	0	0	0
10	0	0	1	1	1
11	0	0	1	1	1
12	0	0	1	1	1
13	1	1	1	1	0
14	1	1	0	0	0
15	0	0	1	1	0
16	0	0	0	0	1
17	0	0	1	1	1
18	0	0	0	0	1
19	0	0	1	1	0
20	1	1	1	1	0
21	1	1	1	1	0
22	1	1	0	0	0
23	0	0	0	0	1
24	0	0	1	1	1
25	0	0	1	1	0
26	0	0	0	0	0
27	0	0	0	0	1
28	1	1	1	1	0
29	1	1	1	1	0
30	0	0	1	1	1

Table 4 shows the result of controller testing. LC in Table 3 is logic checker, VS is vehicle status, HC is horn controller, HS is horn status, and VC is vehicle controller. LC is a sensor representing the VS. VS is the actual condition of the vehicle. If the vehicle is turned on then the VS value is 1 and the LC value is also 1. If the vehicle is turned off then the VS value is 0 and the LC value is also 0. The proposed device works as a scenario if the actual vehicle status (VS) is the same as the logic checker (LC). HC is the controller to turn on and turn off the vehicle horn. HC and HS are always VC is the actuator to control the vehicle, The proposed device works as a scenario if the HC and HS have the same value. Different from all the other statuses, VC is the status for controllingling the vehicle. If the value of VS is 0 then the vehicle works as usual. It can be turned on and turned off by the owner using a key. If the value is 1 then the vehicle cannot be turned on. If the vehicle is turned on then the VS changes from 0 to 1 then the vehicle will be turned off. It can be seen in Table 3 on data number 3. The actual value of LC and VS is 1. It indicates that the vehicle is used and turned on. After several hours, VS changes from 0 to 1 and the vehicle is turned off. This phenomenon can be observed in VS and LC status change from 1 to 0. It indicates that the vehicle is turned off and cannot be turned on if the VC changes from 1 to 0. According to the test result, the proposed device works follows the given rule.

The final test is an experiment with real scenario of vehicle theft. This final test consists of testing while the logic checker detects theft action and theft action according to the distance change. This final test is actual data to prove that the proposed device works to detect vehicle theft.

Table 5. Harvesine Method Performance Compared with Online Platform

No	SC	d (m)	LC	HS	VS
1	1	2.00	0	0	0
2	1	2.25	0	0	0
3	1	2.15	0	0	0
4	1	2.13	1	1	1
5	1	2.17	0	1	0
6	0	3.53	0	0	0
7	1	3.25	0	0	0
8	1	16.53	0	1	0
9	1	17.23	0	1	0
10	1	17.80	0	1	0
11	0	2.73	0	0	0
12	1	2.75	1	1	1
13	1	6.73	0	1	0
14	1	10.24	0	1	0
15	1	15.17	0	1	0

Data from Table 5 shows that the security system works as Figure 4. The security system from Table 5 is stated by the SC label. In this test, SC will always be in active condition. Active condition will bring logic 1 and not active is 0. Data number 4 shows that vehicle theft is triggered by turning on the vehicle while the security system is active. The trigger comes from the LC signal. After LC sends signal 1, the vehicle horn will be active and can be seen in HS status from Table 5. Right after the security system is triggered, the vehicle status immediately changes from 1 to 0. This condition makes the vehicle cannot be used. Data 6 shows that the security system is deceived and all the statuses will be reset. In the data 8 triggers come from distance change. The distance change is 16.53m from the actual location. This condition will trigger the security system and although the logic checker gives 0 signal because the vehicle is not used by the thief. The horn will activate to send the suspicious signal. In the data number 11 security system was already deceived again to reset all the status. According to this information, the security system is triggered by turning on the vehicle. The theft cannot use the vehicle but still wants to steal the vehicle. This condition can be observed from location change that is always wider from the previous location. The security system is already working immediately after the logic checker detects the theft condition.

Figure 7. Sample Data Reading in IoT Platform

Figure 7 shows how the data in IoT Platform Antares is recorded. This recording data is obtained right after the security system is activated. Testing data shows that the proposed device works as planned. The vehicle can be secured, although the location is changed.

Table 6. Peripherals Comparison

Peripherals	**Current Research**	**Research 1 [12]**	**Research 2 [13]**
GPS	√	√	-
SIM800l	√	√	√
Controller	√	√	√
RFID	-	-	√
Relay	√	√	√
Fingerprint Sensor	-	√	√
GPS	√	√	-

Table 6 shows the peripherals comparison with other research. Current research shows fewer peripherals uses compared with other research. Fewer peripherals can lower the production cost. Research 1 [12] uses a fingerprint sensor and research 2 [13] uses RFID and fingerprint sensors to authenticate the motorcycle owner. This feature replaces with IoT platform in the current research. This algorithm means current research does not need the fingerprint sensor. Research 2 uses RFID and fingerprint sensors to authenticate the motorcycle owner. Research 2 does not use GPS but the current research uses GPS. Vehicle location is a crucial function of the vehicle security systems. Research 2 does not provide this feature but the current research provides vehicle location features. This comparison shows that current research has the same feature with fewer peripherals compared with research 1 and has more features with fewer peripherals compared with research 2.

CONCLUSION

The research and experiment data show that the proposed device can detect vehicle theft. The system will recognize vehicle theft when the location changes above 10m or when turning on the vehicle while the security system is active. A feature logic checker and location change successfully triggered the vehicle security system. The proposed device uses few sensors and minimal peripherals compared with other research. Research data shows that the haversine formula can calculate location changes over time. Research data shows that horn control and vehicle control work at 100%. The security system recognizes vehicle theft from logic checkers and location changes. Turning on the motorcycle while the security system is active will trigger the vehicle status. The location change also works right after the vehicle is 15 meters away. This research result proves that the device works as the scenario. The data was also successfully sent to the IoT platform without loss or incompleteness.

ACKNOWLEDGMENT

This research is supported by Lembaga Penelitian dan Pengabdian Kepada Masyarakat (LPPM) Institut Teknologi Telkom Purwokerto.

REFERENCES

[1] BPS, Statistik Kriminal 2022. Badan Pusat Statistik, 2022.

[2] R. Rohmadi, F. Rachman, and Y. Purwanti, "Pencurian Kendaraan Bermotor Ditinjau dari Aspek Krimnologi," Viva Themis J. Ilmu Huk., vol. 2, no. 1, pp. 1–10, Sep. 2020, doi: 10.24967/vt.v2i1.766.

[3] S. N. Christie, P. Yuliartini, and Dewa Sudika Mangku, "Tinjauan Kriminologis Terhadap Tindak Pidana Pencurian Kendaraan Bermotor Di Kota Singaraja," J. Komunitas Yust. Univ. Pendidik. Ganesha Progr. Stud. Ilmu Huk., vol. 4, no. 1, pp. 119–125, 2021.

[4] S. Seriyanti, "Upaya Penanggulangan Pencurian Kendaraan Bermotor Yang Dilakukan Oleh Remaja," Indones. J. Crim. Law, vol. 2, no. 1, pp. 56–64, Feb. 2020, doi: 10.31960/ijocl.v2i1.389.

[5] M. A. Gustalika, S. Sudianto, D. C. Fransisca, F. M. Wibowo, M. A. Afandi, and R. D. Wahyuningrum, "Implementation of the Internet of Things for Flood Mitigation and

Environmental Sustainability," in 2022 IEEE International Conference on Communication, Networks and Satellite (COMNETSAT), Nov. 2022, pp. 426–431, doi: 10.1109/COMNETSAT56033.2022.9994492.

[6] A. K. Putri, A. Prakasa, and M. A. Afandi, "Sistem Pemantau Densitas Debu Gudang Elektronik: Perancangan dan Analisanya," J. Telecommun. Electron. Control Eng., vol. 3, no. 2, pp. 81–86, Dec. 2021, doi: 10.20895/jtece.v3i2.367.

[7] A. A. W. Aisyah, H. Pujiharsono, and M. A. Afandi, "Sistem Monitoring dan Kontrol Pakan Budidaya Ikan Lele menggunakan NodeMCU berbasis IoT," J. Telecommun. Electron. Control Eng., vol. 4, no. 2, pp. 108–116, Jul. 2022, doi: 10.20895/jtece.v4i2.533.

[8] N. F. N. Azizah, H. Pujiharsono, and M. A. Afandi, "Sistem Pengendali Suhu dan Kadar pH pada Kolam Ikan Lele Berbasis IoT pada Desa Kutaringin Kabupaten Banjarnegara," JRST (Jurnal Ris. Sains dan Teknol., vol. 6, no. 1, p. 65, Nov. 2022, doi: 10.30595/jrst.v6i1.11693.

[9] H. R. Maulida, F. T. Syifa, and M. A. Afandi, "Analisis dan Perancangan Prototipe untuk Memonitoring Lahan Perkebunan Teh menggunakan LoRa," J. Telecommun. Electron. Control Eng., vol. 4, no. 2, pp. 117–127, Jul. 2022, doi: 10.20895/jtece.v4i2.538.

[10] N. Maharani Raharja, M. Arief Fathansyah, and A. Nur Nazilah Chamim, "Vehicle Parking Security System with Face Recognition Detection Based on Eigenface Algorithm," J. Robot. Control, vol. 3, no. 1, pp. 78–85, Oct. 2021, doi: 10.18196/jrc.v3i1.12681.

[11] H. Isyanto, A. Solikhin, and W. Ibrahim, "Perancangan dan Implementasi Security System pada Sepeda Motor Menggunakan RFID Sensor Berbasis Raspberry Pi," Resist. (elektRonika kEndali Telekomun. tenaga List. kOmputeR), vol. 2, no. 1, p. 29, May 2019, doi: 10.24853/resistor.2.1.29-38.

[12] T. Juwariyah, D. Widiyanto, and S. Sulasmingsih, "Purwa Rupa Sistem Pengaman Sepeda Motor Berbasis IoT (Internet of Things," J. Otomasi Kontrol dan Instrumentasi, vol. 11, no. 1, p. 49, May 2019, doi: 10.5614/joki.2019.11.1.5.

[13] Astuti, Nuraeni Puji, R. Ritzkal, A. H. Hendrawan, and B. A. Prakosa, "Vehicle Security System using Short Message Service (SMS) as a Danger Warning in Motorcycle Vehicles," J. Robot. Control, vol. 1, no. 6, 2020, doi: 10.18196/jrc.1642.

[14] J. K. Maulidin, A. Hiswara, and R. Sari, "Designing Motorcycle Security System Using E-KTP Sensor and SMS Gateway," PIKSEL Penelit. Ilmu Komput. Sist. Embed. Log., vol. 9, no. 2, pp. 161–172, Sep. 2021, doi: 10.33558/piksel.v9i2.3073.

[15] K. Purwanto, Iswanto, T. Khristanto, and M. Yusvin, "Microcontroller-based RFID, GSM and GPS for Motorcycle Security System," Int. J. Adv. Comput. Sci. Appl., vol. 10, no. 3, 2019, doi: 10.14569/IJACSA.2019.0100357.

[16] R. Ananda and M. Amin, "Use of KTP to Activate Start Motorcycle Engine with Module RC-522," JURTEKSI (Jurnal Teknol. dan Sist. Informasi), vol. 9, no. 3, pp. 515–520, Jun. 2023, doi: 10.33330/jurteksi.v9i3.2495.

[17] R. Muzawi, Y. Irawan, D. Akhiyar, and D. Setiawan, "Pattern Lock and GPS-Based Motorcycle Security System," Int. J. Eng. Trends Technol., vol. 70, no. 3, pp. 185–194, Mar. 2022, doi: 10.14445/22315381/IJETT-V70I3P221.

[18] B. Artono, T. Lestariningsih, R. G. P. Yudha, and A. A. Bachri, "Motorcycle Security System using SMS Warning and GPS Tracking," J. Robot. Control, vol. 1, no. 5, 2020, doi: 10.18196/jrc.1531.

[19] Chandra Husada, Kristoko Dwi Hartomo, and Hanna Prillysca Chernovita, "Implementasi Haversine Formula untuk Pembuatan SIG Jarak Terdekat ke RS Rujukan COVID-19," J. RESTI (Rekayasa Sist. dan Teknol. Informasi), vol. 4, no. 5, pp. 874–883, Oct. 2020, doi: 10.29207/resti.v4i5.2255.

[20] R. Hidayati and N. Mutiah, "Penerapan Metode Haversine Formula Pada Pencarian

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

Lokasi Fasilitas Kesehatan Terdekat," J. MEDIA Inform. BUDIDARMA, vol. 6, no. 1, p. 278, Jan. 2022, doi: 10.30865/mib.v6i1.3445.

[21] A. Hakim and M. Saefudin, "Aplikasi Sistem Informasi Geografis Menggunakan Metode Haversine Formula Pencarian Rumah Kost Daerah Jakarta Selatan," J. Inf. Syst. Informatics Comput., vol. 5, no. 2, p. 397, Nov. 2021, doi: 10.52362/jisicom.v5i2.640.

[22] M. Liviandra, Z. K. A. Baizal, and R. Dharayani, "Conversational Recommender System for Impromptu Tourists to Recommend Tourist Routes Using Haversine Formula," J. MEDIA Inform. BUDIDARMA, vol. 5, no. 4, p. 1224, Oct. 2021, doi: 10.30865/mib.v5i4.3229.

[23] H. R. Hatta, M. H. Suroso, I. F. Astuti, D. M. Khairina, and S. Maharani, "Application of Haversine Formula in Education Game 'Landmark Nusantara,'" 2021, doi: 10.2991/aer.k.210810.039.

[24] S. Winoto, A. Fadlil, and R. Umar, "Penerapan Haversine Formula Pada Penerimaan Peserta Didik Baru Jalur Zonasi," J. MEDIA Inform. BUDIDARMA, vol. 4, no. 1, p. 103, Jan. 2020, doi: 10.30865/mib.v4i1.1573.

[25] U. Syaripudin, N. Fauzi, W. Uriawan, W. Z, and A. Rahman, "Haversine Formula Implementation to Determine Bandung City School Zoning Using Android Based Location Based Service," 2020, doi: 10.4108/eai.11-7-2019.2303558.