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Smart Helmet Based on Microcontroller for Motorcyclists

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Abstract

Motorcycles are one of the most popular types of transportation used by people in Indonesia. However, the use of motorcycles has its own risks and problems such as the high number of motorcycle accidents. Human error is one of these factors, for example not paying attention to the distance with the vehicle in front and using a smartphone while driving. In addition, the problem of helmet theft is one of the factors that reduce driving safety. This research aims to create a smart helmet that helps reduce the use of smartphones while driving, provide safe distance notifications between vehicles, and create a tracking system in case of theft. This research uses hardware which includes nodemcu esp32, hc-sr04 sensor, neo 6m gps module, and max98357 i2s audio amplifier module and software including telegram for notification and control and programming using ardiuno IDE. After the experiment, all components and systems of this smart helmet are able to work as expected and in line with the research objectives. The application of this smart helmet can help overcome the use of smartphones while driving, know the safe distance with the vehicle in front and assist in finding a helmet in the event of theft.

Keywords: Smart helmet; Human Error; Esp32; Module GPS Neo 6M; HC-SR04.

1. Introduction

Motorcycles are one of the land transportation options that can be used when traveling in Indonesia. Their ease of use and efficiency make motorcycles favored by various segments of society [1]. Approximately 85% of Indonesia's population are motorcycle riders, making Indonesia one of the countries with the highest motorcycle usage in the world. However, this high usage also brings risks and other issues, such as accidents while riding [2].
In order to overcome this problem, the government made regulations written in Law No. 22 of 2009 for reference for every motorcyclist in Indonesia [3]. However, based on data collection from the Ministry of Transportation in 2021, the number of land transportation accidents reached 103,645 cases and as many as 73% of the cases were dominated by motorcycles [4]. Many factors cause such cases to occur frequently and the most common factor is the human error factor. Human error is a factor caused by negligence or mistakes made by humans, for example violating regulations that have been set such as not using a helmet, not applying a safe distance when driving, using a smartphone when on the road and others [5]. Taking an example of a human error case that has occurred, quoted from news.okezone.com [6], there were 2 motorcyclists who died after being hit by a car due to using Google Maps while driving on the Jogja-Solo crossroad. Another example of a case quoted from banten.antaranews.com [7], a teenager died after crashing into the back of a Toyota Avanza car on Jl. Scientia Boulevard, caused by driving fast and not applying a safe distance while driving. In addition to these examples, there are other cases that need to be considered, where this factor occurs due to negligence or intentionality carried out by motorcycle users. The case in question is a case of losing a helmet that is rampant in places with low security such as the absence of CCTV supervisors or security guards. Based on the

case that occurred at the Faculty of Computer Science Brawijaya, there were as many as 12 out of 30 students who filled out the questionnaire had experienced helmet theft [8]. This has a direct impact on the safety of motorcyclists, in addition to the financial losses that occur, the loss of a helmet as a safety attribute also makes riders more vulnerable to severe injuries in the event of an accident [9].

In order to overcome some of the problems caused by these factors, problem solving is needed that aims to help overcome them, such as taking a problem-solving method with the development of a smart helmet. Smart helmet is an integrated electronic helmet that prioritizes comfort and safety for its users by adding a global locating system, interactive sensor features with the environment, a mobile network communication device, and several other helpful features [10].

Based on existing research, many use different methods such as develop a smart helmet to notify if there is a beheading by providing the location of the GPS (Global Positioning System) coordinates of the motorcyclist to the closest relatives [11]. Developed Smart Helmet and Blind Spot Detection for Motorcyclist Safety Features to help drivers reduce blind spot areas when driving by utilizing the HC-SR04 sensor to find out which vehicles are in the blind spot area [12]. The last method makes smart helmets use interactive sensors for riders by showing accident-prone areas [13].

Taking some concepts from the research above, the author can raise a smart helmet theme with the title "Smart Helmet Based on Microcontrollers for Motorcyclists". The purpose of this final project is to develop a conventional helmet into a smart helmet. Based on the Esp32 NodeMCU as a microcontroller and the built-in Bluetooth feature of the Esp32 as an audio data transfer used to overcome the use of smartphones while driving [14], create a distance notification system with the vehicle in front using the HC-SR04 sensor, and help track the location of the helmet in the event of theft using the Neo 6 M GPS Module [15].

2. Material and methods

Tool design in this study uses literature methods and experimental methods. The literature study method uses journals to obtain guaranteed information. While the experimental method uses the design, manufacture and testing of hardware and software to achieve the desired results [16]. Design for hardware which includes the mechanical framework and components of the overall control of the tool. Software design which includes flowcharts and program systems applied to the system. As well as a design that includes diagram blocks that aim to find out how the system works as a whole [17].

Diagram blocks are used to interpret the design of task tools [18]. With this, it can be known which components are included in the input and output, in figure 1 this is a block diagram that will explain the process of running the tool as a whole.

The working principle of this smart helmet uses 2 NodeMCU Esp32 pieces as microcontrollers that work separately, where the first is used for the main system of the smart helmet, and the second is for the Bluetooth audio system. This is so that the system does not hinder each other when working. In order for the system to work, make sure to first activate the switch connected to the battery. After the system works, there is a notification from the helmet when connected to the internet network. This notification is in the form of a voice output from the mini DFPlayer connected to the right speaker and a chat displayed on the Telegram Chabot. The main system of the smart helmet actually works when the switch is activated and the internet connection is connected. In this system, there are 2 other systems that work at the same time. The system works when it gets input from the HC-SR04 sensor and the Neo 6M GPS Module. The HC-SR04 sensor is used as a system for measuring the safe distance of the vehicle in front, by placing it in the chin vent on the full face helmet. This system works automatically where later when a vehicle in front of the driver is detected entering a distance of ≤350cm from the helmet position, the system automatically gives a warning to the driver continuously until the distance between the driver and the vehicle in front exceeds 350cm. The form of warning given is the sound output of the file stored on DFPlayer mini. Meanwhile, the Neo 6m GPS Module is used in a tracking system with command input coming from Telegram. This system works when the rider feels that he or she has lost his helmet, by entering a tracking command in a Chabot that has been created on Telegram, the system automatically requests location data that has been collected from the GPS module. The data will later be displayed as a reply to the tracking command. In addition to tracking commands, there are also commands to turn the buzzer on and off which is useful for knowing where the helmet is. The Bluetooth audio system works when the connection is a Bluetooth connection, so the NodeMCU Esp32 that works here is the second. Where all audio data output from the smartphone is transferred and received by NodeMCU. The audio data in the form of digital data will later be converted into analog data through the Amp Module. Max 98357 I2S, so it can be directly connected to the speaker.

To make a programming from a tool, a flowchart is needed to help in writing instructions and controlling the algorithm in the programming [19]. In this final project, the author uses 2 flowcharts consisting of a smart helmet system flowchart and a Bluetooth audio system flowchart. You can observe the Figure 2 to see the tool's flowchart.

The design of this tool includes hardware design to facilitate physical aspects of the device, software design to ease the creation of non-physical components, and electronic circuits that serve as guidelines for system circuit design.

In the design of hardware tools, the design is divided into 2 designs, namely the design of the outside of the helmet and the inside of the helmet. This design was done using SketchUp to design it. To observe the hardware design you can see figure 3 and 4.

The outside hardware design it's important to know that in the smart helmet hardware design, we use a full-face helmet and modify it by adding some components. In this part of the helmet there is an HC-SR04 sensor which is used to detect the vehicle in front and on the back of the helmet there is an antenna from the neo 6m GPS module

While in the design of the inside smart helmet hardware there is a component that controls the work of the tool. These components can be seen from the numbering in each picture, starting from Sensor HC-SR04, GPS antenna, Neo 6M GPS Module, Switch/switch, 5V Step-down Module, Battery, NodeMCU Esp32, Buzzer, DFPlayer Mini, Speakers, Module Amp. MAX98357 I2S.

The software design in this final project utilizes the telegram application to check the status of the helmet and track the system when the helmet is lost. In addition, the use of Arduino IDE as a program creation and uploading programs on the MCU Node board. To observe display of telegram you can see figure 5.

The electronic circuit design aims to assist in the creation of devices and clarify the relationships between related systems on the pins of the intended device In this final project, the electronic circuit design is divided into 2 circuits To view these circuits, please refer to Figure 6 below.

Table 1: Esp32 NodeMCU Network connection test status

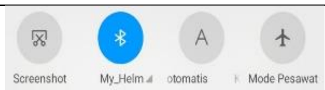
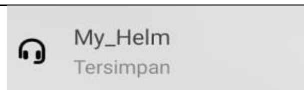
No.	Connection	Visual On Smartphone	
		Connected	Disconnected
1.	Bluetooth		
2.	Internet		-

Table 2: Tracking Testing using the Neo 6M GPS module.

No	Test Tracking (Coordinate Display)	Room Conditions		Error (m)
		Inside	Outside	
1.	www.google.com/maps/place/-0.943140,100.396762	✓	-	10 m
2.	https://www.google.com/maps/place/-0.891028,100.350620	✓	-	8 m
3.	www.google.com/maps/place/-0.846797,100.376408	-	✓	9 m
4.	www.google.com/maps/place/-0.860867,100.381158	✓	-	7 m
5.	www.google.com/maps/place/-0.889422,100.394512	-	✓	-
6.	www.google.com/maps/place/-0.907630,100.403085	✓	-	12 m
7.	www.google.com/maps/place/-0.929417,100.367303	-	✓	-

Table 3: Testing of the HC-SR04 sensor on Road Banjir Kanal Alai Parak Kopi.

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	Many vehicles	0
2.	20	10	few vehicles	0
3.	30	10	few vehicles	1
4.	40	10	few vehicles	0

Table 4: Testing of the HC-SR04 sensor on Road Jati Adabiah.

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	Many vehicles	0
2.	20	10	Many vehicles	0
3.	30	10	Many vehicles	0
4.	40	10	few vehicles	1

Table 5: Testing of the HC-SR04 sensor on Road Tunggul Hitam.

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	Many vehicles	0
2.	20	10	Many vehicles	1
3.	30	10	Many vehicles	0
4.	40	10	few vehicles	1

Table 6: Testing of the HC-SR04 sensor on Road Khatib Sulaiman.

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	few vehicles	0
2.	20	10	Many vehicles	0
3.	30	10	Many vehicles	0
4.	40	10	Many vehicles	0
5.	50	10	Many vehicles	1
6.	60	10	few vehicles	1

Table 7: Testing of the HC-SR04 sensor on Road Jendral Sudirman.

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	Many vehicles	0
2.	20	10	Many vehicles	0
3.	30	10	Many vehicles	1
4.	40	10	Many vehicles	1
5.	50	10	Many vehicles	0
6.	60	10	few vehicles	1

Table 8: Testing of the HC-SR04 sensor on Road Prof. Hamka

No.	Vehicle Speed (km/h)	Experiments conducted (Times)	Road Conditions	Error
1.	10	10	Many vehicles	0
2.	20	10	Many vehicles	0
3.	30	10	Many vehicles	0
4.	40	10	Many vehicles	1
5.	50	10	Many vehicles	0
6.	60	10	few vehicles	1

Table 9: Overall HC-SR04 Sensor Test Results.

No.	Testing Locations	*Δ* Testing	Average Road Condition	Average Speed	Error
1.	Jl. Banjir Kanal	40	few vehicles	40 km/h	1
2.	Jl. Jati Adabiah	40	Many vehicles	40 km/h	1
3.	Jl. Khatib Sulaiman	60	Many vehicles	60 km/h	2
4.	Jl. Jendral Sudirman	60	Many vehicles	60 km/h	3
5.	Tunggul Hitam	40	Many vehicles	40 km/h	2
6.	Jl. Prof. Hamka	60	Many vehicles	60 km/h	2
Total Testing		300	Total *Error*		11

Table 10: Overall Tool Testing.

No.	Usage Time (Hours:Minutes:Seconds)	Features Used			*Error*	Description
		ESP32 (Audio)	HC-SR04 (Distance)	GPS Neo 6M (*Tracking*)		
1.	3:01:21	-	✓	-	Notification	Notifications from DFPlayer mini become late when usage exceeds 2 hours of use
2.	2:26:30	✓	✓	-	Audio Transfer	Audio Transfer is interrupted when the device's battery is about to run out
3.	2:40:20	-	-	✓	Location gain and buzzer	Location delivery stops when the battery is about to run out, and in this condition the buzzer will not work
4.	2:20:05		✓	✓	-	The error condition is still the same as points 2 and 3
5.	1:36:50	✓	✓	✓	Power consumption	Power consumption when using all features becomes very wasteful.

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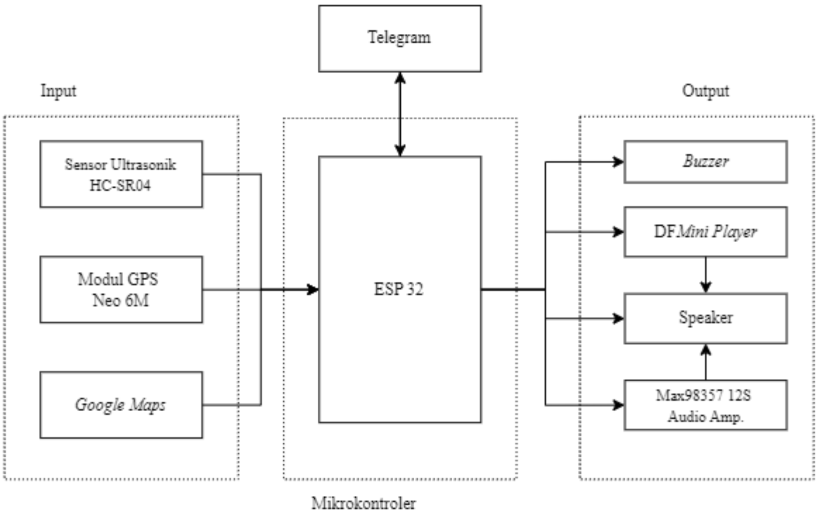
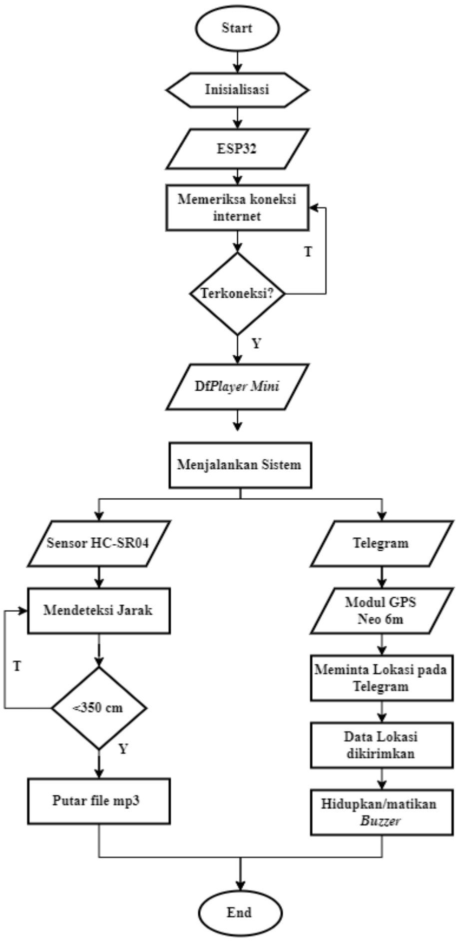
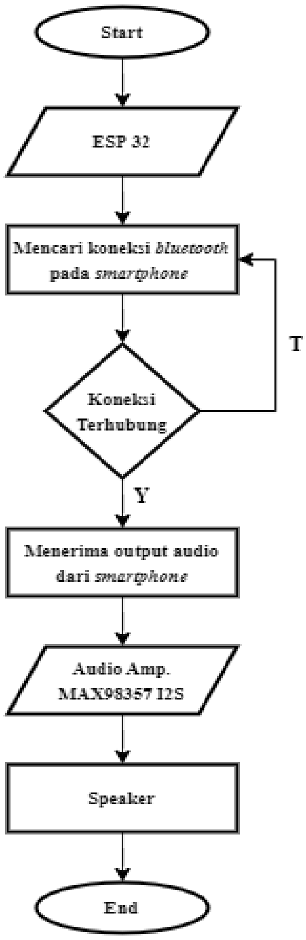


Figure 1: Block Diagram of the Whole System.



(a)



(b)

Figure 2: System flowchart figure, (a) System Smart helmet, (b) Audio Transfer Bluetooth.

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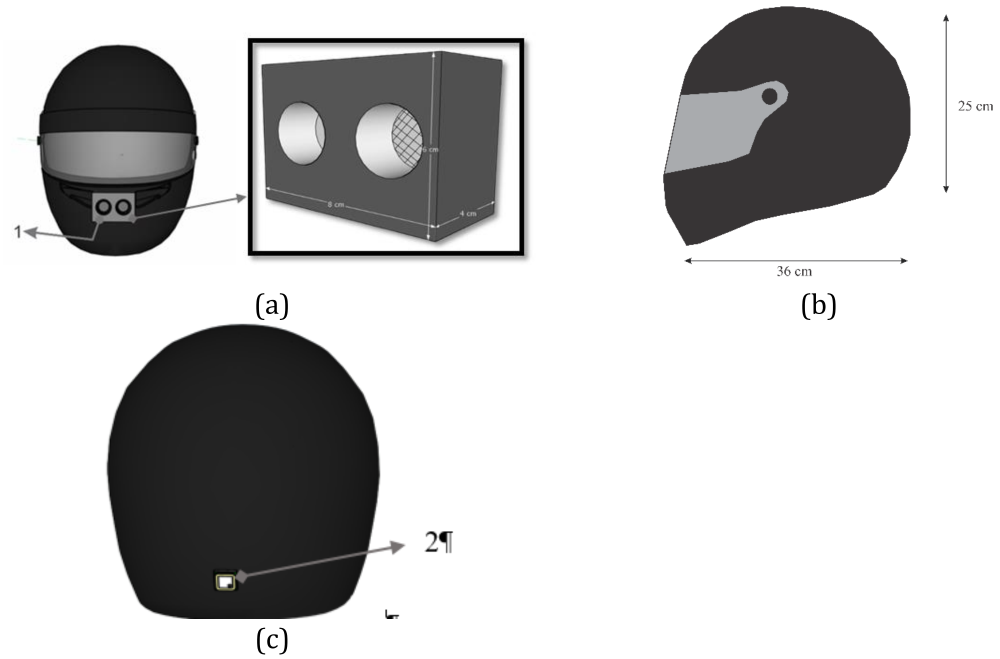

Figure 3: Hardware Design Outer View, (a) View From ahead, (b) View From Beside (c) View From Behind.

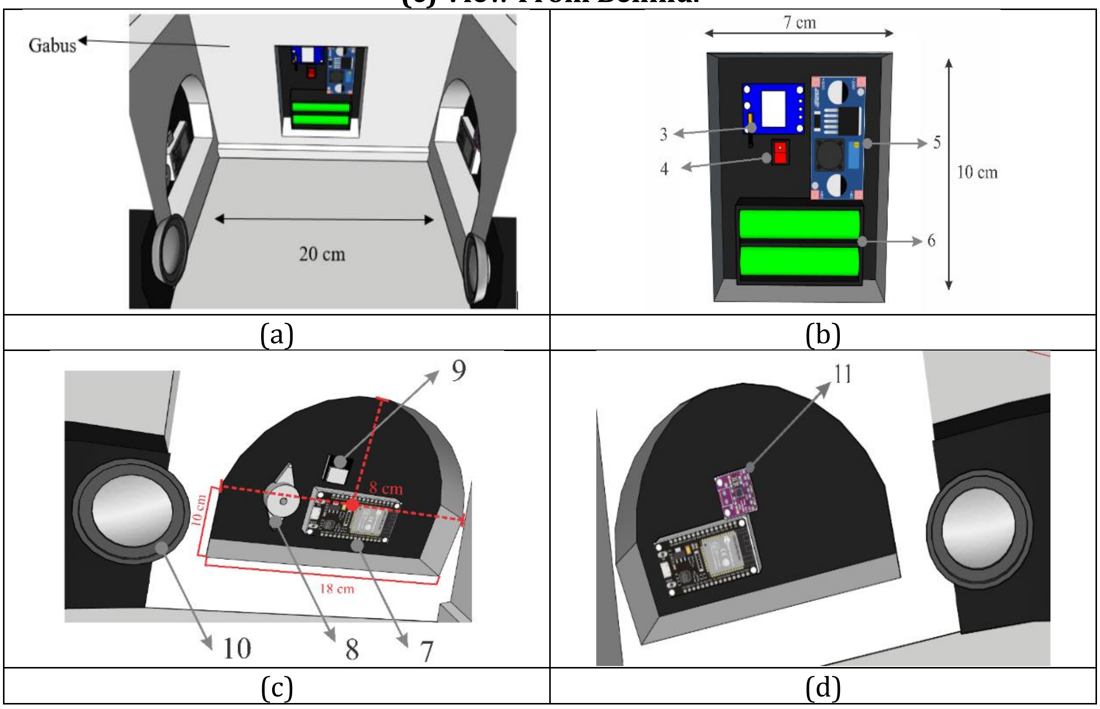

Figure 4: Hardware Design Inside View, (a) Overall Design, (b) View back side (c) View right side, (d) View left side.

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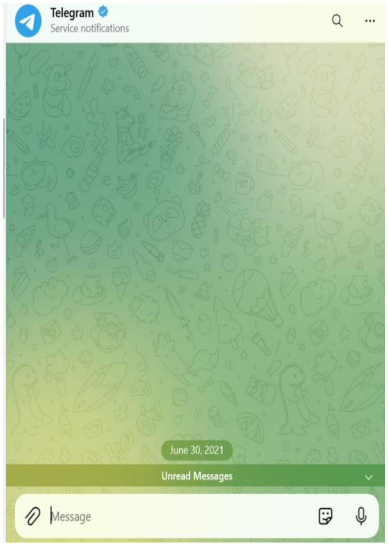
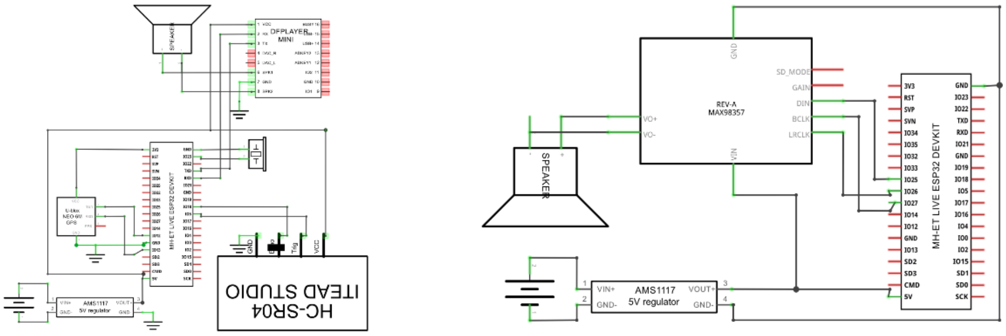


Figure 5: Chat display on Telegram.



(a) (b)

Figure 6: Electronic Circuit Design, (a) System Smart helmet, (b) Audio Transfer Bluetooth.

(a) (b)

Figure 7: Mechanical Results Outer View, (a View From ahead, (b) View From Behind.

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(a)

(b)

(c)

Figure 8: Mechanical Results inside View, (a) View right side, (b) View left side (c), View back side.

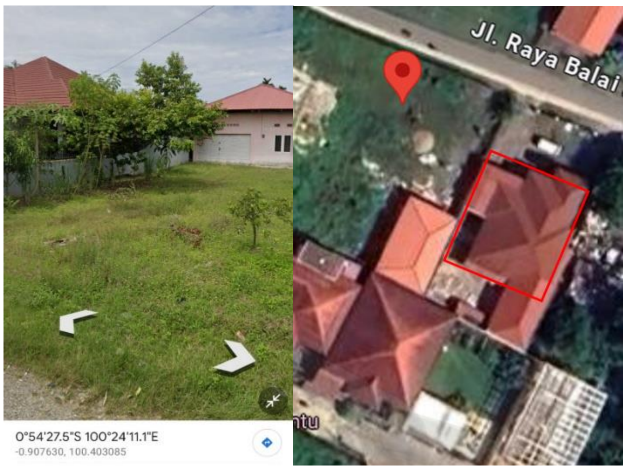

Figure 9: Smart helmet location display on the Google Maps application.

Figure 10: Final project link Program.

Figure 11: ChatBot display on Telegram.

The formula to find the effectiveness of the hc-sr04 sensor is as follows.

$$\%Efficacy = \frac{Total\ Tests - Total\ Errors}{Total\ Tests} \times 100\% \quad (1)$$

3. Results and discussion

A tool is said to be successful and works well, requiring a test to get the results of the tool. This section describes the process of testing and collecting data of the tool, which is useful for analyzing the performance of the tool. Testing includes data and final results from the hardware and software tools that have been made. Based on these data, an analysis of the work process can be carried out, with the aim of drawing conclusions from the tools that have been made in this Final Project.

A. System Mechanical Results.

The system mechanics are the physical form of the entire hardware design of the smart helmet that has been designed, plus the location of all the components used.

To see the results of the mechanics that have been created, look at pictures 7 and 8.

B. Hardware Testing.

Hardware testing aims to determine if the system works according to the design of the device and the flowchart that was created in this smart helmet, the testing includes checking the network connection status of the NodeMCU Esp32, GPS tracking, and distance measurement

1. Testing the NodeMCU Esp32 network connection status.
   This test aims to determine the connection from the Bluetooth network and the internet on the Esp32 NodeMCU. The experiment was carried out by paying attention to the status of the Bluetooth icon on the smartphone and the telegram notification on the screen. To see the test results, you can see the following table 1.
2. Testing of the tracking system using the Neo 6M GPS module.
   In testing this system, the experiment was carried out in the form of testing the accuracy of the tracking system of the Neo 6M GPS module. In this test, the data taken consisted of indoor and outdoor tracking data and errors that occurred. The error here is an error that occurs when the helmet is at a tracking point that is far from the actual location of the helmet. For data collection here, a tape measure is used in meters (m). To see the test results, you can see the following table 2.
   In the test table, there are only the coordinates of the tracking results displayed on the Chabot on Telegram. To see the location more clearly, you can just press the link directly so that it is redirected to the Google Maps application on your smartphone. In the test table there are errors that often occur in indoor helmet testing. This is because the accuracy level of the GPS signal is compromised when there is a building covering it. There are also cases of errors that occur in outdoor testing. This case occurs very rarely, as it happens because the road or building is not registered in the Google Maps system. To understand more clearly, consider figure 9 which is an example of indoor test results in table 2 of coordinate's number 6.
3. Testing of vehicle distance indicators using HC-SR04 sensors.
   This test is carried out to find out that the sensor performance is in accordance with what is needed, by testing on several roads that have different vehicle intensities. The test will be carried out by classifying the condition of "many vehicles" and "few vehicles" roads. For "many vehicles" the number of vehicles during the test exceeded 3 vehicles, while "few vehicles" was below 3 vehicles. The vehicle speed is set from 10km/h-60km/h. To see the data that has been taken, pay attention to table 3-8.
   For tables 3, 4 and 5, the test was carried out with a speed limit of only up to the speed limit of 40 km/h due to small and short road conditions.
   Based on the test tables that have been carried out, there are still several errors that have occurred. Common errors are caused by a system that detects too late and sensor conditions that are not straight up with the object because the helmet is too upward. For the system factor, it is late to detect most cases because there are only a few vehicles in front of the driver. Moreover, the vehicle is only a motorcycle, the system is always late detecting it because the detected object is too small. To see all the results, the test can be seen in table 9 below.
   After getting the overall test results and errors, it can now be calculated how much percent of the effectiveness of the system has been created with the following formula [20].

C. Software Testing.

For software testing of this tool, the author divides it into Telegram Chabot testing and programming testing. The programming of the system tool here uses the C programming language and the software used is Arduino IDE. The tests are as follows.

1. Programming Testing.
   Programming is the core of this tool, without programming the tool cannot work. Programming is done to make the system so that it can be used properly. To see the program lists, scan the code in figure 10 below.

2. Testing Telegram Chabot.

For testing here, it will only display the Chabot form on Telegram named with the "Smart Helm" bot [21]. To understand how the program works, please first see the list code above. Here is the form of its appearance that can be seen in figure 11.

In this software test, the test is carried out by trying all the keywords that have been prepared in the previous program, such as “Cek lokasi”, “Hidupkan Buzzer”, and “Matikan Buzzer”.

D. Testing of the overall tool working system.

Overall system testing is a series of tests aimed at testing the performance of the device while it is in operation. At this stage, the device is operated normally by pressing the switch on the battery, after which the device will be tested using all existing features such as the use of the hc-sr04 sensor, tracking the system using the neo 6M GPS module, and audio transfer using esp 32.

The data collection process uses the above method to determine the time limit for using the device, which is affected by how long the battery lasts when all features are used. In addition to looking at the limitations of using the tool, this method is also used to find out the problems (errors) that occur when the tool is used continuously. The overall system test data can be seen in table 10.

In the process of collecting this data, there are many errors that occur due to the battery capacity. This makes the tool not recommended for long-distance travel because the tool will quickly run out of power. As for the performance of the entire system, there are no significant problems. For notifications, they are only interrupted when the system has been on for more than 2 hours, which is a result that can be said to be quite good when used in driving under normal conditions.

4. Conclusion

Based on the results of the design and tests that have been conducted, the following conclusions can be made. The smart helmet based-microcontroller functions as expected and aligns with the research objectives. The components, such as the HC-SR04 sensor test and the Esp 32, perform as well. For example, the HC-SR04 sensor detects vehicles in front with a success rate of 96.33%, and the Esp 32 effectively transfers audio. The Neo 6M GPS module as a helmet tracking system can track the location of helmets indoors and outdoors well even though there is a distance from the original location. The use of Chat Bot on Telegram as a tracking control can work well according to the purpose. The tool comprehensively produces data in the form of a helmet that can work in a range of 3 hours to 1 hour. This data makes the tool work well overall but cannot be used for long-distance travel.

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