Developing Electrical System Analysis of Car Floor Vacuuming Robot Based on Dust Sensor

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Abstract

This research addresses the increasing demand for automated cleaning solutions, particularly for vehicle interiors, where traditional manual cleaning methods often prove inefficient and time-consuming. The primary aim of this study is to develop an autonomous robot vacuum cleaner capable of cleaning the floor of a vehicle by detecting dust or dirt, using a proximity sensor to avoid obstacles, and operating based on input from a dust sensor. The research follows a systematic process, including topic selection, literature review, design challenges, system design, testing, and result analysis, to evaluate the performance and limitations of the proposed system. The results of this research indicate that the robot operates effectively, with optimal movement achieved when the battery voltage ranges between 12.2V and 10.9V. Below 10.9V, the robot's movement becomes suboptimal. The 60W vacuum cleaner on the robot successfully collects debris such as paper pieces, tissue scraps, and fine soil particles. In conclusion, this car floor vacuuming robot, based on a dust sensor, demonstrates satisfactory functionality in terms of system performance, battery life, movement, and cleaning capability. The study suggests potential for further development, particularly in enhancing technical design and integrating advanced technologies such as autonomous navigation and the Internet of Things (IoT).

Keywords: Robot Vacuum Cleaner, Dust Sensor, Proximity Sensor, Car Floor.

I. INTRODUCTION

Car interior cleanliness is an important factor in maintaining the comfort and health of its users. One part that is often overlooked is the cleanliness of the car floor. Car floors are often a place for dust and other dirt to accumulate, especially from passenger footwear, and in cars, dust or dirt on the floor or carpet can also be sucked into the evaporator [1]. If not cleaned regularly, it can cause the room in the car to become smelly and can cause respiratory infections such as coughing [2]. Manual cleaning of the car floor using a broom takes time and effort, so many people neglect it. On the other hand, modern technologies such as robot vacuum cleaners have been proven to help clean dust efficiently [3]. However, most robot vacuum cleaners do not have distance sensors such as ultrasonic sensors or photoelectric proximity sensors, and dust sensors that are used to read dust values, so that the movement of robot vacuum cleaners is only based on object collisions because it cannot detect the distance of an object, and the vacuum cleaner on the robot cannot be controlled automatically.[4].

Numerous studies have been conducted on the development of vacuum robots, with various sensor technologies integrated to enhance their functionality. One such study focused on a prototype utilizing the Optical Dust Sensor GP2Y1010AU0F, which showed limited performance due to the sensor's high sensitivity to air [5]. Attempts to improve dust cleaning were made by incorporating ultrasonic sensors and additional dust sensors. However, the absence of a relay to regulate the vacuum cleaner's motor led to suboptimal performance, as the dust sensor was used solely for reading dust values without controlling the vacuum's operation [6]. Similar issues were observed in several studies, including one on an Arduino Uno-based automatic robot vacuum cleaner prototype, where the addition of ultrasonic sensors did not include dust sensors or relays, limiting the robot's ability to control the vacuum cleaner motor based on dust detection [7].

Other research efforts sought to incorporate advanced technologies, such as Bluetooth modules and Android controls, to improve the user interface and operational control of the vacuum cleaner robot. Despite these advancements, several key shortcomings were identified, primarily the lack of ultrasonic sensors for navigation and dust sensors for detecting dust levels. Without these essential sensors, the vacuum cleaner could not operate autonomously or efficiently. Further research introduced additional components such as photoelectric proximity sensors and relays to address some of these limitations, but issues with energy efficiency persisted due to the use of non-optimal power sources, like regular batteries, instead of lipo batteries, which would improve the robot's mobility and performance [8], [9], [10].

Recent studies continued to explore the integration of various sensors, such as ultrasonic sensors, Bluetooth modules, and proximity sensors, in attempts to enhance the autonomous capabilities of vacuum robots. However, a recurring limitation across these studies is the failure to incorporate dust sensors and relays for controlling the vacuum motor. This omission prevents the automatic activation or deactivation of the vacuum cleaner based on real-time dust detection, thereby reducing the overall effectiveness of these systems [11], [12], [13], [14]. Moreover, certain designs also lacked the necessary navigation sensors, such as ultrasonic sensors, to ensure autonomous movement [15], [16]. The absence of these critical components consistently hindered the robots' ability to function autonomously and efficiently, underscoring the need for further refinement in sensor integration and control mechanisms for optimal performance [17], [18], [19].

To overcome these problems above, the study is intended to develop a robot vacuum cleaner, by adding an HC-SR04 ultrasonic sensor, photoelectric proximity sensor, and GP2Y1010A0F dust sensor. The HC-SR04 ultrasonic sensor is used to detect the front object on the robot vacuum cleaner, and the photoelectric proximity sensor is used to detect the rear object on the robot, so that the robot can walk automatically to clean dust or dirt, and can avoid or not crash when detecting object, while the GP2Y1010A0F dust sensor has functions as a dust or dirt detector which later the function of this sensor is used to set the relay to be active or inactive based on the dust value read by the dust sensor. The relay will be used to disconnect and connect the current voltage from the battery to the vacuum cleaner dynamo on the robot.

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II. METHOD

In making an electrical system analysis of car floor vacuuming robot based on dust sensor, there are several paths that must be followed so that the manufacture of products can run according to plan. The systematic plan can be seen in the following figure 1.

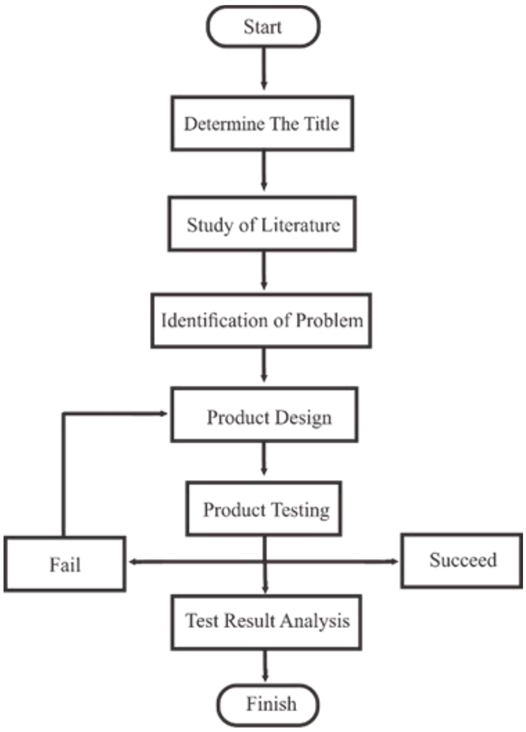

Figure 1 Research Procedures

Figure 1 describes the flow of research, The first time in doing research was to figure out a topic, followed by looking for references to several articles or journals from the internet or books. Furthermore, there were determining problems taken from reference articles or journals. Moreover, there were deficiencies in manufacturing, designing products which include making electrical system designs on robots and programming. That was followed by testing the product to find out what failed and the cause of the problem, either a failure in making the program or a failure in making the electrical system circuit. The test was carried out continuously until it was successful. The last step was to analyze the test results which aim to determine the advantages and disadvantages of making the electrical system analysis of car floor vacuuming robot based on dust sensor.

A. System Workflow Diagram

To make it easier to understand the workflow of each sensor or component used in the manufacture of car floor vacuuming robot based on dust sensor, a system workflow diagram is made as shown in figure 2.

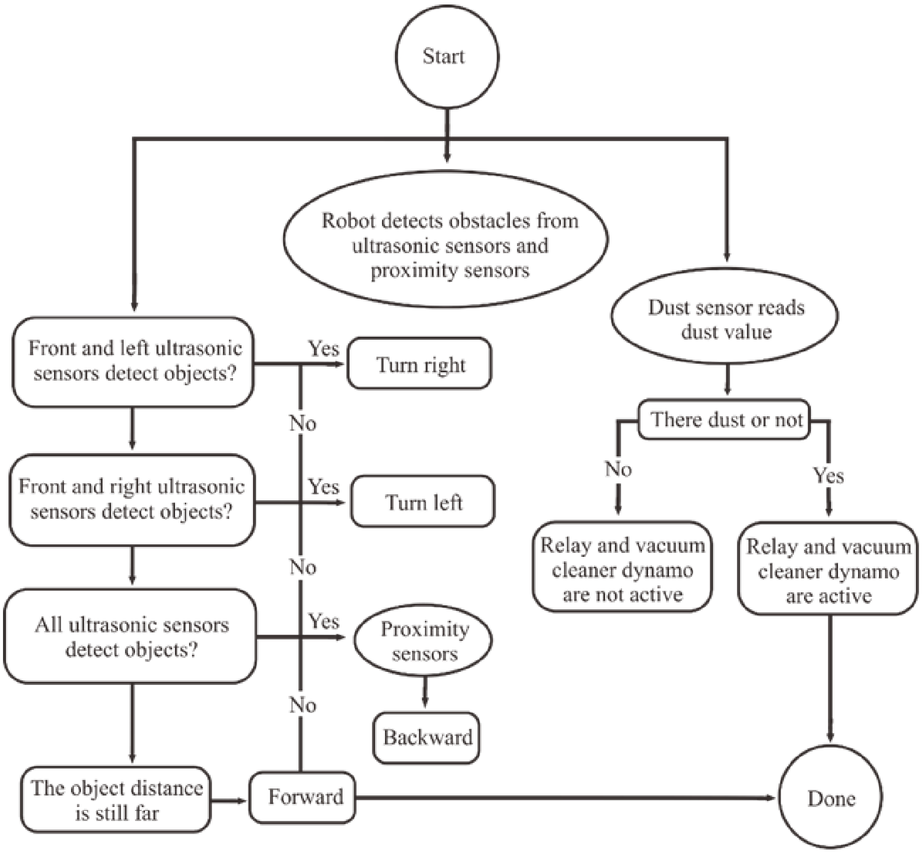

Figure 2 System Workflow Diagram

Figure 2 explains how the automatic work car floor vacuuming robot based on dust sensor, when the switch is turned on the robot vacuum cleaner will be active, and the ultrasonic sensor and proximity sensor begin to detect objects. When the front and left ultrasonic sensors detect an object, the robot will turn right, if it does not detect an object the robot will continue to move forward. When the front and right ultrasonic sensors detect an object, the robot will turn left, if it does not detect an object the robot will continue to move forward. When all ultrasonic sensors detect an object, the robot will move backwards so that the proximity sensor will be active to read the rear object if it does not detect the object, the robot will continue to move forward. When the detected object is still far away, the robot will continue to walk forward. The dust sensor will also be active to read the dust value when the switch on the robot is turned on, when dust is detected by the dust sensor, the relay will be active so that the vacuum cleaner dynamo is also active, otherwise if the dust is not detected by the dust sensor, the relay will be inactive so that the vacuum cleaner dynamo is also inactive.

B. Electrical Wiring Diagram

This electrical wiring diagram is made using the Fritzing application, because this application can clearly display images of electronic components like the original, making it easy to connect the input or output pins to the components [20], as seen in figure 3. In making it starts from downloading the component library on the fritzing application forum, then importing the component library file into the fritzing application, then the next step connects the pin path to each component used by using the wire icon in the Fritzing application. Working drawings or schematic circuits of car floor vacuuming robot based on dust sensor can be exported into JPG, PNG and PDF files.

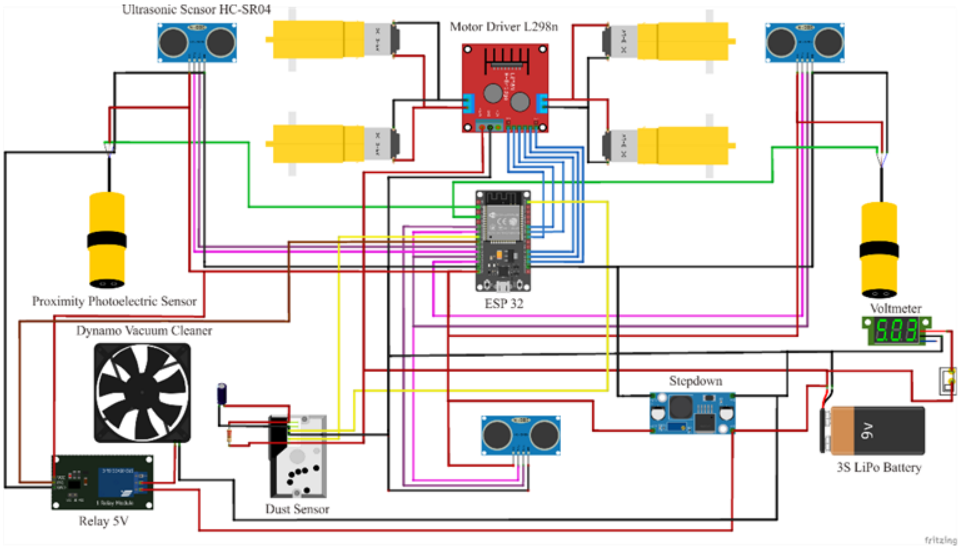

Figure 3 Electrical Wiring Diagram

Figure 3 explains how the working system of the car floor vacuuming robot based on dust sensor, when the switch is turned on the current from the 12V lipo battery will go to the voltmeter which is used to show the voltage, then the 12V current goes to the stepdown module so that the output current becomes 5V which is used to supply such as ESP 32, ultrasonic sensor, photoelectric proximity sensor, input relay, and dust sensor while the motor driver l298n, pin main relay, and vacuum cleaner dynamo are powered by 12V voltage from the lipo battery. The ultrasonic sensor and proximity sensor will provide input distance readings to the ESP 32 to regulate the movement of the L298n motor driver whose output is given wheel dynamo, so that the robot vacuum cleaner can walk and not hit objects. The dust sensor will provide an input reading of the dust value to the ESP 32 in order to command the relay as a switch to regulate the vacuum cleaner dynamo on the robot so that it can be active or inactive based on the reading of the dust value from the dust sensor.

C. PCB Design

Making this PCB design is made through the Easy EDA application, because in it there are many electronic components along with their specifications and features that help in checking the electrical path on each pin of the component being made, so that it can make it easier when you want to make a PCB path design [21], as seen in figure 4.

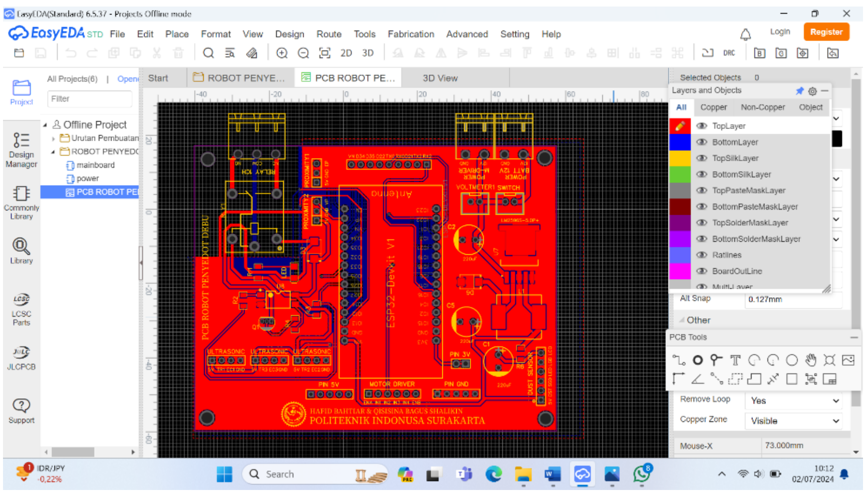

Figure 4 PCB Design

Figure 4 shows that in making PCB designs using a double layer, where to connect the path to the component pin or the placement of electronic components can be divided into 2 parts, including the top layer and bottom layer, making it easier to make PCB designs and making it easier to connect the path to the pin of the electronica component.

Figure 5 Final Result of PCB Design

In the process, it starts from downloading the component library in the Easy EDA application which has a footprints so that when displayed in a 3D image, the image can be seen clearly, then connecting the pins to each component using the net port icon, after the circuit schematic is complete, the next step is to convert the circuit schematic to PCB and made using 2 paths, namely the top layer and bottom layer with the aim of making it easier to connect the path to each component, checking the PCB path can be done after all components have been connected using the DRC check icon. Figure 5 shows the final result of making the PCB design and is ready to be printed.

D. Programming

Making this program is made through the Arduino IDE application, which plays a role in helping to write programs, add component libraries, test programs, and then upload them into memory on a microcontroller, thus making input or output operations easier and faster [22], as seen in figure 6.

Figure 6 Control System Programming on Car Floor Vacuum Cleaner Robot

Programming through the Arduino IDE application does not require the ESP 32 library to be able to connect directly via Wi-Fi or Bluetooth, because in making this car floor vacuuming robot based on dust sensor work automatically, this ESP 32 is programmed to be able to work automatically without requiring Wi-Fi or Bluetooth. In figure 6, making a program through the Arduino IDE application starts from declaring the pins of each component, making calculation formulas from each sensor so that they can work, making commands through void setup which aims to make pin data on sensors or components so that they can be used as input and output in carrying out the process of how it works, making void loops with the aim of executing all commands made through void setup.

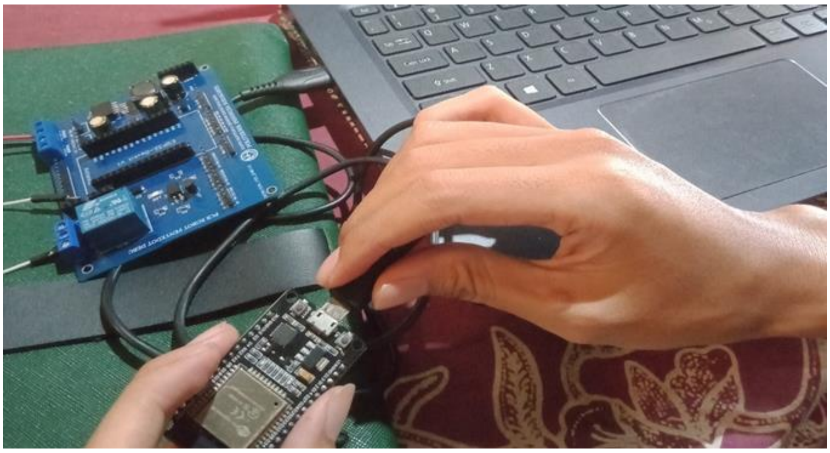

Figure 7 Uploading Programs

After the program has been created, then check the program created through the verification icon found on the Arduino IDE application menu tollbar, so that you can find out whether or not it fails in making the work program [23]. In Figure 7 is the process of uploading the program from the Arduino IDE to the ESP 32, it takes the type of USB cable of an ordinary mobile phone charger in carrying out a communication or transferring a program that has been made through the Arduino IDE.

E. Robot Design

The design of this car floor vacuuming robot based on dust sensor is made using the Fusion360 application, because it has advanced features that make it easy to make designs, such as simulation, rendering, and animation [17]. Making the design starts from measuring all sizes such as the components used [24]. Then starting to make the design of each component separately in order to facilitate the manufacture and connection process of each component.

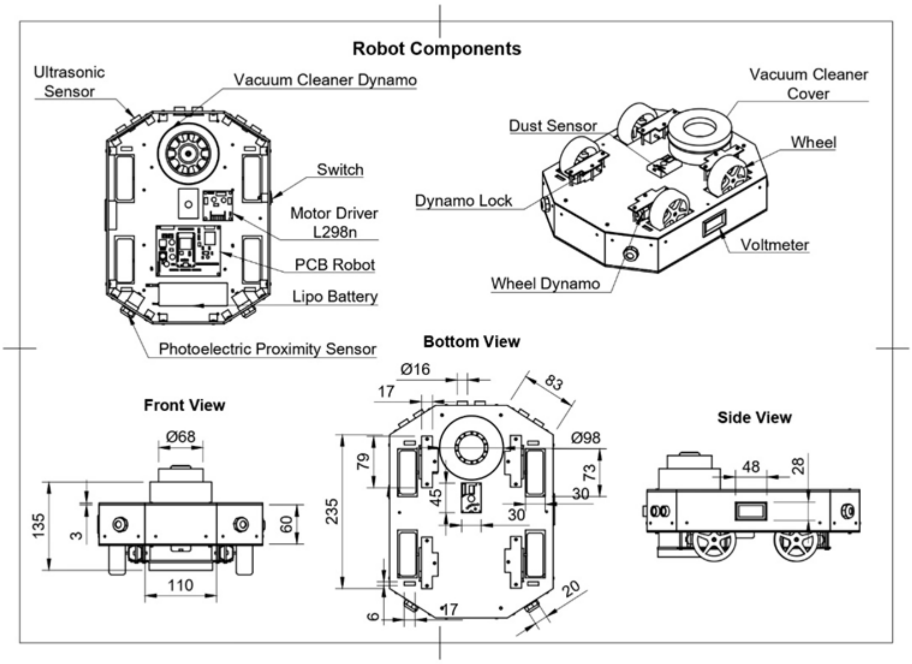

Figure 8 Robot Size and Description

In Figure 8 contains the size and information about the placement of each component used in making a car floor vacuuming robot based on dust sensor, for the placement of ultrasonic sensors placed on the front because as a front object detector, while the photoelectric proximity sensor is placed on the back of the robot as a rear object detector on the robot. The placement of the dust sensor is placed under the robot and so that it can easily detect dust or dirt on the floor of the car. The provision of a wheel dynamo lock aims to make the wheel dynamo not easily separated when the robot moves forward, backward, turns right or turns left.

F. Assembly

Before analysis the test results of the electrical system of car floor vacuuming robot based on dust sensor, the assembly is carried out first.

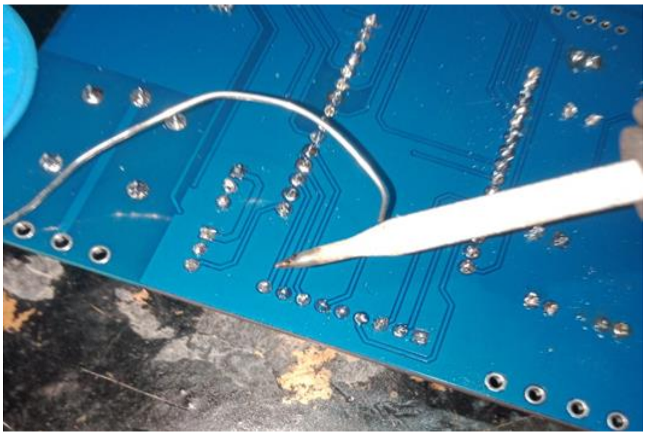

Figure 9 Component Pin Soldering

In Figure 9 shows the process of soldering the component pins, to facilitate the installation of the components used such as, capacitors, resistors, diodes, LED lights, PC817 optocouplers, header pins, relays, and LM2596S, a paste-shaped flux liquid is needed before soldering so that the installation of components on the PCB board is easier to stick perfectly and also does not cause marks such as burns on the PCB board, when installing components or removing components on the PCB board.

Figure 10 Final Assembly Result

In this process, the electrical circuit assembly of the electrical system of car floor vacuuming robot based on dust sensor is carried out, which includes pin installation components such as ultrasonic sensors, photoelectric proximity sensors, dust sensors, switches, lipo batteries, voltmeters, and vacuum cleaner dynamos into the vacuum cleaner robot PCB, using jumper cables to connect them. For the assembly of pin lines to these components, according to the circuit schematic design in figure 3 made through the Fritzing application. Figure 10 is the final result of assembling the dust sensor-based car floor vacuum robot.

III. Results and Discussion

A. Testing the Working System of Car Floor Vacuuming Robot Based on Dust Sensor

This test is designed to thoroughly evaluate the functionality and performance of the car floor vacuuming robot, which is based on a dust sensor, to ensure that the system operates at its full potential. The test focuses on verifying that each component of the system works seamlessly, starting with the ultrasonic sensors that detect obstacles and measure distances accurately. In addition, the photoelectric proximity sensors must function properly to detect the presence of objects in close proximity. Furthermore, the relays should be able to respond correctly to the control signals, activating or deactivating the vacuuming system as needed. Most importantly, the dust sensors must accurately measure dust levels in the environment, triggering the appropriate actions in the system. All these components must work in harmony, as programmed through the Arduino IDE application, to ensure that the robot operates effectively and efficiently according to the intended design specifications.

Table 1 Testing the Working System of Car Floor Vacuuming Robot Based on Dust Sensor

No	Test Scenario	Expected Results	Results
1	Pressing the ON/OFF switch button	If you press it to on, the robot will turn on, otherwise if you press it to off, the robot will turn off.	Succeed
2	Making the robot turn left	If the front and right ultrasonic sensors or the right ultrasonic sensor alone detects an obstacle, the robot will turn left.	Succeed
3	Making the robot turn right	If the front and left ultrasonic sensors or the left ultrasonic sensor alone detects an obstacle, the robot will turn right.	Succeed
4	Making the robot move forward	If the left, front, and right ultrasonic sensors detect no obstacles, the robot will move forward.	Succeed
5	Making the robot move backward	If the left, front, and right ultrasonic sensors detect an obstacle, the left and right photoelectric proximity sensors will be active, causing the robot to move backwards.	Succeed
6	Making the dust sensor work to activate or deactivate the relay	If there are dust or dirt particles on the dust sensor reader area, the relay will activate according to the program that has been made.	Succeed

In table 1 above shows, the test results of the work system on the robot can function properly, starting from pressing the ON or OFF switch button, making the robot turn left, making the robot turn right, making the robot walk forward, making the robot walk backward and finally making the dust sensor work to activate or deactivate the relay that connects the dynamo vacuum cleaner on the robot. Based on the results of testing the working system of the car floor vacuuming robot based on dust sensor, nothing fails because it is in accordance with the function of the program made through the Arduino IDE application, and in the installation of the pin path to the components also in accordance with the electrical wiring diagram as in Figure 3, which is made through the Fritzing application. Based on previous research testing entitled Designing a Smart Vacuum Cleaner Using the IOT-Based Fuzzy Logic Mamdani Method [14]. There was a failure in testing the ON/OFF button and the ultrasonic sensor used could not read the object, because there was an error in making the program code and the wiring diagram path was not appropriate. Similar things also exist in the testing of previous research entitled Design of a Dust Cleaning Robot [25]. There was a failure in testing the connectivity distance of the Bluetooth HC-05 module, where at a distance of 12 meters the Bluetooth connection was lost. From the comparison results above, testing the working system of the car floor vacuuming robot based on dust sensor carried out today is more effective. This is because the robot can move automatically without requiring control via smartphone, and the electrical path has used PCB, so that the components used can be connected to each other more accurately.

B. Battery Life Consumption Calculation

The calculation of battery life consumption is a critical process to assess the performance and efficiency of the 2200 mAh LiPo 3S battery used in the car floor vacuuming robot, which is based on a dust sensor system [26]. This analysis is essential for determining the operational endurance of the robot, providing insights into how long the vacuuming system can function before requiring a recharge. By evaluating factors such as power consumption rates of the vacuum motor, dust sensor, and other electrical components, it becomes possible to estimate the duration of continuous use under varying conditions. Additionally, the calculation helps identify potential inefficiencies in the power management system and offers opportunities to optimize battery usage for extended operation. Ultimately, understanding the battery life is crucial for ensuring the robot's reliability and effectiveness in performing its tasks without frequent interruptions.

Table 2 Battery Life Consumption Calculation

No	Component Load	Specification		
		Voltage (V)	Ampere (A)	Power (*Watt*)
1	Dynamo Vacuum Cleaner	12V	5A	60W
2	L298n Motor Driver	12V	2A	24W
3	4 Wheel Dynamo	5V	0,40A	8W
Total Power Consumption				**92W**

From the table 2 above is the consumption of power calculations on the workload of car floor vacuuming robot based on dust sensor components such as, vacuum cleaner dynamo which has a specification of 60W, L298n motor driver which has a specification of 24W, and wheel dynamos which have a specification of 8W, after that the total workload of the components used is summed up, then the overall result is 92W. Then to find the time how long the durability of the lipo 3s battery will last, if given a load of components such as a vacuum cleaner dynamo, L298n motor driver as follows:

Battery Capacity = 2200 mAh = 2.2 Ah

Battery Power = 2.2 Ah × 12,2V = 26.84 Wh

$$\text{Battery Life} = \frac{\text{Battey Power}}{\text{Total Power Consumption}}$$

$$= \frac{26.84 \text{ Wh}}{92 \text{ W}}$$

$$= 0{,}291 \text{ h} = 0{,}291 \text{ x } 60 = 17{,}5 \text{ minutes}$$

Based on the results of the above calculations, the lipo 3s battery life on the car floor vacuuming robot based on dust sensor can last for 0.291 hours or 17.5 minutes. While testing previous research entitled Automatic Floor Cleaning Robot Based on Arduino Uno [27]. Battery life on the robot vacuum cleaner is able to last for 0.832 or about 50 minutes by having a battery capacity of 9000 mAh. The same thing also exists in previous research testing entitled Application of Fuzzy Methods to Vacuuming Robots [13]. Battery life on a robot vacuum cleaner can last about 15 minutes, from the results of the test comparison above to make the robot vacuum cleaner on the floor of the car can work longer in cleaning, it requires a lipo 3s battery type above 2200 mAh.

C. Battery Testing and Robot Movement Conditions

Before conducting tests on the battery and the condition of the robot movement, the battery is charged first until it is fully charged at 12.2V, in approximately 1 hour.

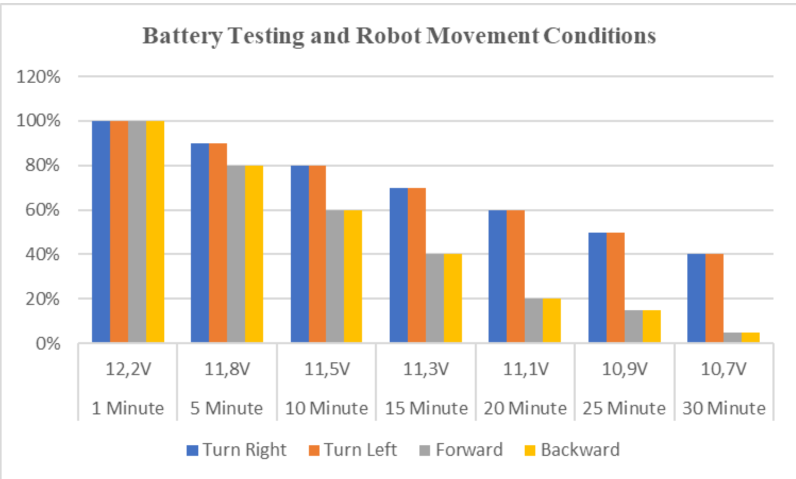

Figure 9 Battery Testing Graph and Robot Movement Conditions

Based on the results of battery testing and the condition of the movement of the car floor vacuuming robot based on dust sensor, the data in figure 12 above shows that the robot can move optimally for 25 minutes, or it can be concluded that the movements of the robot vacuum cleaner such as forward, backward, right turn and left turn are optimal when the power from the battery is at a voltage of 10.9V to 12.2V, under a voltage of 10.9V the movement is not optimal such as forward and backward movements due to the forward or backward movement of the direction of rotation of the wheel dynamo together so that the power released by the lipo 3s battery is greater than when the movement turns right or left. In this test, the vacuum cleaner dynamo is made active or inactive based on the dust sensor reading, so that the robot can work optimally for 25 minutes, while according to the calculations in table 2 above the lipo 3s battery used in the robot can last for 17.5 minutes, because the vacuum cleaner dynamo on the robot output power is measured to be active continuously without pause, so that the robot can move optimally for 17.5 minutes.

D. Testing the Vacuum Cleaner on the Robot

This test is carried out to find out the vacuum cleaner on the robot is able to suck what kind of object, in conducting this experiment there are types of objects provided such as pieces of paper, pieces of tissue, fine soil grains, small pebbles and sand.

Tabel 2 Testing the Vacuum Cleaner on the Robot

No	Object Type	Battery	Testing Result
1	Paper Pieces	12,2V	The paper pieces can be sucked up easily by the vacuum cleaner on the robot
2	Tissue Pieces	12,2V	The tissue pieces can be sucked up easily by the vacuum cleaner on the robot
3	Fine Soil	12,2V	The fine soil can be sucked up easily by the vacuum cleaner on the robot
4	Grains of Sand	12,2V	The grains of sand can be not sucked up by the vacuum cleaner on the robot
5	Small Pebbles	12,2V	The small pebbles can be not sucked up by the vacuum cleaner on the robot

Based on the results of vacuum cleaner testing, from table 2 above shows that the battery used to supply the vacuum cleaner dynamo has a current of 12.2V and a vacuum cleaner with 60W power on the robot is able to suck objects such as pieces of paper, pieces of tissue, and fine grains of soil, while objects such as grains of sand and small pebbles vacuum cleaner on the robot is not able to suck it. Based on the test results of the Dust Suction Robot Prototype Design Using Optical Dust Sensor GP2Y1010AU0F [5]. When the robot is operated, the vacuum cleaner dynamo with 9W power cannot suck heavy objects such as sand. Similar things also exist in the Design of Smart Vacuum Cleaner Using IOT-Based Mamdani Fuzzy Logic Method [14]. When the robot is operated, the vacuum cleaner dynamo with 36W power is only able to suck small dust such as fine soil grains, from the comparison results of the above tests to make the vacuum cleaner dynamo can suck objects such as small gravel and sand, a type of vacuum cleaner dynamo with power above 60W is needed.

IV. CONCLUSION

The electrical system of the car floor vacuuming robot, which utilizes a dust sensor for its operation, has been thoroughly evaluated and found to function optimally. This conclusion is supported by detailed calculations of battery life consumption, which confirm that the robot can run for a continuous period of 17.5 minutes on a single charge. A comprehensive analysis of the battery's performance, combined with the robot’s movement conditions, revealed that the system works most efficiently when the battery voltage is maintained between 10.9V and 12.2V. This voltage range ensures efficient power distribution, enabling the robot to function stably and reliably during its operation. Additionally, further testing of the vacuuming system revealed that the robot achieves its optimal performance at a power level of 60W, striking an ideal balance between energy efficiency and effective suction power. The robot proves excellent cleaning capabilities, particularly in terms of dust collection and supporting floor surfaces. Moreover, the robot’s sensors allowed it to effectively detect and avoid obstacles both in front and behind, ensuring smooth navigation throughout its cleaning process. It also exhibits autonomous movement, following a set path to clean the floor efficiently, removing dust, dirt, and debris. Overall, the analysis confirms that robots excel in both performance and autonomy.

REFERENCES

[1] E. Gowasa, A. Afdal, V. Selviyanty, R. Abu, and M. Mukhnizar, "Analisis Perbaikan dan Pemeliharaan Sistem Pendingin (Air Conditioner) Pada Mobil Jazz New," *J. Tek. Ind. Terintegrasi*, vol. 6, no. 3, pp. 770–780, 2023, doi: 10.31004/jutin.v6i3.17096.

[2] A. Hidayat, "Dampak polusi udara pada kesehatan," *Univ. Medan Area*, pp. 1–12, 2023, doi: https://doi.org/10.31219/osf.io/wam46.

[3] I. P. A. B. Ni Luh Ketut Inggitarahayu, Anggasemara, I Made Agus Dwi Suarjaya, "Rancang Bangun Penyedot Debu Berbasis Internet of Things," *Walisongo J. Inf. Technol.*, vol. 5, no. 1, pp. 1–14, 2023, doi: http://dx.doi.org/10.21580/wjit.2023.5.1.16123.

[4] A. R. P. Muhamad Taufiq Tamam, "Prototipe Robot Pembersih Lantai Berbasis Mikrokontroler," *J. Inform. dan Tek. Elektro Terap.*, vol. 11, no. 3, pp. 703–709, 2023, doi: 10.23960/jitet.v11i3.3285.

[5] E. F. Dafit Setia Lasmana, "Rancang bangun prototype robot penghisap debu menggunakan optical dust sensor GP2Y1010AU0F," *Bina Darma Conf. Eng. Sci.*, pp. 20–29, 2020, [Online]. Available: http://conference.binadarma.ac.id/index.php/BDCES

[6] R. H. Dhoni Hidayatullah, Diva Adesta Putra Afrizen, Maria Ulfa, Muhammad Fairuz Ivandyaputra, Sheva Maulana Ardy Syah Putra, "Desain Prototype Robot Vacuum Cleaner Otomatis Berbasis Arduino Uno," *J. Komput. dan Elektro Sains*, vol. 2, no. 1, pp. 14–17, 2024, doi: 10.58291/komets.v2i1.159.

[7] W. Yahya and D. D. Yulianto, "Uji Konektifitas Smart Security Control Pada Sepeda Motor Menggunakan Arduino Nano Dan App Inventor 2," vol. 07, no. September, pp. 45–50, 2022.

[8] T. Yudha Prawira, Y. Lestari, and S. Muhammadiyah Paguyangan Brebes, "Perancangan Robot Penghisap Debu Berbasis Arduino Uno Dengan Kontrol Android," *J. Tek. Inform. dan Sist. Inf.*, vol. 3, no. 1, pp. 15–21, 2023.

[9] C. I. Rapa, E. Dephtios, C. Mariangga, and N. Patiung, "A Design and Build A Robot Vacuum Cleaner," *J. Phys. Conf. Ser.*, vol. 2394, no. 1, 2022, doi: 10.1088/1742-6596/2394/1/012024.

[10] S. C. Hsia, S. H. Wang, J. Y. Yeh, and C. Y. Chang, "A Smart Leaf Blow Robot Based on Deep Learning Model," *IEEE Access*, vol. 11, no. October, pp. 111956–111962, 2023, doi: 10.1109/ACCESS.2023.3307136.

[11] Ikhwan Taufik, Fuad Hilmy, Xander Salahudin, and El Vionna Laellyn Nurul Fatich, "Pelatihan Rancang Bangun Mini Vacuum Cleaner Robot untuk Mendukung Program 'Santri Berdikari, Mandiri Teknologi' di Desa Kalirejo Magelang," *JURPIKAT (Jurnal Pengabdi. Kpd. Masyarakat)*, vol. 5, no. 2, pp. 602–610, 2024, doi: 10.37339/jurpikat.v5i2.1756.

[12] D. Desmulyati, H. Saiyar, M. H. Siregar, and M. Noviansyah, "Vacuum Cleaner Robot with Arduino R3 Android Based," vol. 4, no. 2, pp. 958–965, 2024.

[13] A. Yulio, K. Aulisari, and M. Orisa, "Penerapan Metode Fuzzy Pada Robot Penyedot Debu," *JATI (Jurnal Mhs. Tek. Inform.*, vol. 5, no. 1, pp. 45–52, 2021, doi: 10.36040/jati.v5i1.3330.

[14] C. Nanda *et al.*, "Rancang bangun smart vacuum cleaner," vol. 8, no. 6, pp. 11950–11954, 2024.

[15] A. Amir, M. Basri, M. Supardi, and M. Sukardi, "Sistem Kendali Pergerakan Robot Omni-Wheel," pp. 157–161, 2023.

[16] R. C. Ginting and S. Yakub, "Implementasi real time clock (RTC) pada robot line Blok Diagram," *J. Teknol. Komput. dan Sist. Inf.*, vol. 1, no. 1, pp. 8–12, 2021, [Online]. Available: http://jurnal.goretanpena.com/index.php/teknisi

[17] H. A. Azizul, Ilham Agus Candra Lubis, "Rancang Bangun Robot Alat Pel Berbasis Nodemcu Esp8266 Menggunakan Android," *Semin. Nas. Ind. dan Teknol.*, no. November, pp. 220–229, 2022.

[18] Hasanudin, "Analisis Robot Sensor Pendeteksi kotoran Debu Dan Air Pada Lantai Rumah Dengan sensor ultrasonik Universitas Trunojoyo Madura," pp. 202–205, 2023.

[19] A. Rahmi, N. P. Acla, D. F. Hidayati, and S. Hardiyanti, "Robot penyedot, pengepel dan pengering lantai (VAMOR)," no. Adomako 1975, pp. 44–57, 2024.

[20] F. Hady, M. Sholeh, and D. Andayati, "Pengembangan Prototipe Aplikasi Membuka Kunci Pintu Otomatis Menggunakan Metode Sidik Jari Berbasis Nodemcu," *J. Comput. Sci. Technol.*, vol. 2, no. 1, pp. 1–7, 2022, doi: 10.54840/jcstech.v2i1.17.

[21] S. Fuada *et al.*, "Studi EasyEDA sebagai Alternatif Simulator Rangkaian Listrik : Pengujian pada Rangkaian Mesh dan Pembuktiannya dengan Eksperimen Aktual," *Aliener J. Tek. Electro ITN Malang*, vol. 4, no. 2, pp. 80–90, 2023, [Online]. Available: www.elektro.itn.ac.id

[22] A. Wijaya and D. Juliadi, "Rancang bangun robot pembersih lantai menggunakan arduino nano dengan sistem pengendali berbasis android," *Tek. Inform. Fak. Tek. Univ. Muhammadiyah Bengkulu*, vol. VIII, no. September, pp. 98–107, 2021, doi: www.ejournal.unib.ac.id/index.php/pseudocode.

[23] W. Yahya and C. A. Pamungkas, "Design of voice control system an android and arduino-assisted as a component activation on vehicles," *Mech. Eng. Educ.*, vol. 4, pp. 1–10, 2019, [Online]. Available: http://jurnal.untirta.ac.id/index.php/vanos ISSN 2528-2611

[24] A. Zolfagharian, A. Kaynak, and A. Kouzani, "Closed-loop 4D-printed soft robots," *Mater. Des.*, vol. 188, p. 108411, 2020, doi: 10.1016/j.matdes.2019.108411.

[25] D. M. R. D. A. W. Irawan, "Rancang Bangun Robot Pembersih Sungai dengan Image Processing," *JATI (Jurnal Mhs. Tek. Inform.*, vol. VIII, no. September, pp. 98–107, 2023, doi: https://doi.org/10.36040/jati.v7i4.7440.

[26] R. Rizaldi, S. D. Panjaitan, and M. Saleh, "Analisis Unjuk Kerja Unmanned Aerial Vehicle (UAV) Hexacopter Pada Lahan Pertanian," *Progr. Stud. Sarj. Tek. Elektro Jur. Tek. Elektro, Fak. Tek. Univ. Tanjungpura*, 2021.

[27] M. Ihsan and M. Rahmawaty, "Robot Pembersih Lantai Otomatis Berbasis Arduino Uno," *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 1, pp. 332–344, 2023, doi: https://doi.org/10.24036/jtein.v4i1.397.