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Development of Solar Panel Cleaning Robot for Residential Sector

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Abstract: The function of solar panel is to absorb the solar energy and convert it into the electricity. Hence, it is required to install the solar panel at the open area to absorb maximum radiation of sunlight. Due to install the solar panel in open area, the solar panel easily to be soiling due to the dust, bird pooping and pollen. Thus, the solar panel cannot absorb the maximum radiation of sunlight. Hence, the solar panel need to be clean in order to generate maximum electricity. Mostly, people used manual cleaning to clean solar panel but manual cleaning is known as old method and not an effective way because it takes long duration in cleaning the solar panel and this method is costly due to use a lot of water consumption. Thus, the main objective of this project is to design and develop solar panel cleaning robot. This project has proposed to use dry cleaning method by using two types of brush which are nylon brush and microfiber brush. Besides that, Arduino IDE software is used to receive and process the control signal from the sensor and send the processed signal to the microcontroller which is Arduino to control the movement of the solar panel cleaning robot and the movement of nylon brush. The robot able to move around the solar panel according to the proposed movement where the robot will turn right when the distance of solar panel with the robot is 2.5 cm and above while if the distance is below 2.5 cm, the robot move forward. Besides that, from the result it found that the robot able to clean the solar panel under two condition which are when the solar panel is dusted and the surface of solar panel have leaves.

Keywords: Nylon brush, Microfiber brush, Arduino IDE

1. Introduction

In 2010, Malaysia was introduced to The Low Carbon Cities Framework (LCCF) to become low carbon cities by using renewable energy [1]. The government was targeted to reduce 40% carbon emission reduction by 2020 compared to 2005 levels. Therefore, the developers and city planner were recommended to reduce 40% carbon emission in development of cities. Thus, Green Home Concept was introduced to the people. The purpose of the concept is to reduce carbon emission reduction that produce by the conventional house [2]. Due to the solar energy does not produce gas emissions and not

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pollute the environment it was introduced to the people as an effective way to achieve Green Home Concept.

Solar energy is one of the renewable energies that used photovoltaic technology which is solar panels to convert the radiation of solar to the electricity. The sunlight that absorbs by the solar panel will make electron start to moving to produce electric current if the solar panel can gain enough energy [3]. So, the solar panels need to be installing directly exposed to sunlight to make sure it can gain enough energy and operate with high efficiency. Therefore, solar panels need to be installed at the open area either on the rooftop or ground mounted array to absorb the maximum radiation of sunlight [4].

Due to installing the solar panel in open areas, the solar panel easily to be soiling because of the air pollution that produces dust and other dirt. Therefore, the performance of the solar panel to absorb maximum radiation of the sunlight will reduce 6% to 16.5% [5]. Hence, the surface of the solar panels needs to be clean to ensure the solar panels can absorb the maximum radiation of sunlight. There are several ways to clean up the solar which are by using natural cleaning, manual cleaning, pressure water, water spray cleaning, steam cleaning, creepy robot cleaner and Eccoppia E4 [6]. Each of the method has advantages and disadvantages in term of cost, time, effectiveness and safety. Therefore, the goal of this project to develop solar panel cleaning robot with a high performance in cleaning the solar panel. In this project, Arduino IDE software will be use to simulate the coding. Besides that, to get high effectiveness in cleaning the solar panel, microfiber brush and nylon brush has been proposed to use.

2. Materials and Methods

In order to develop solar panel cleaning robot, electrical design, mechanical design and the system of solar panel cleaning robot have been determined. This section will explain in details the electrical design, mechanical design and the proposed algorithm of solar panel cleaning robot.

2.1 Electrical Design

The electric circuit in this project as shown in Figure 1 consists the connection of Arduino UNO, battery, three DC motor, motor driver L298N, ultrasonic sensor, and capacitive proximity sensor as stated in Table 1. Based on the circuit, the power of ultrasonic sensor will be supplied from 3.3V pin port Arduino UNO. While 5V pin port of Arduino UNO power up 5V of relay. Meanwhile, Arduino UNO been power by connect Vin pin port to the 5V pin port motor driver L298N.

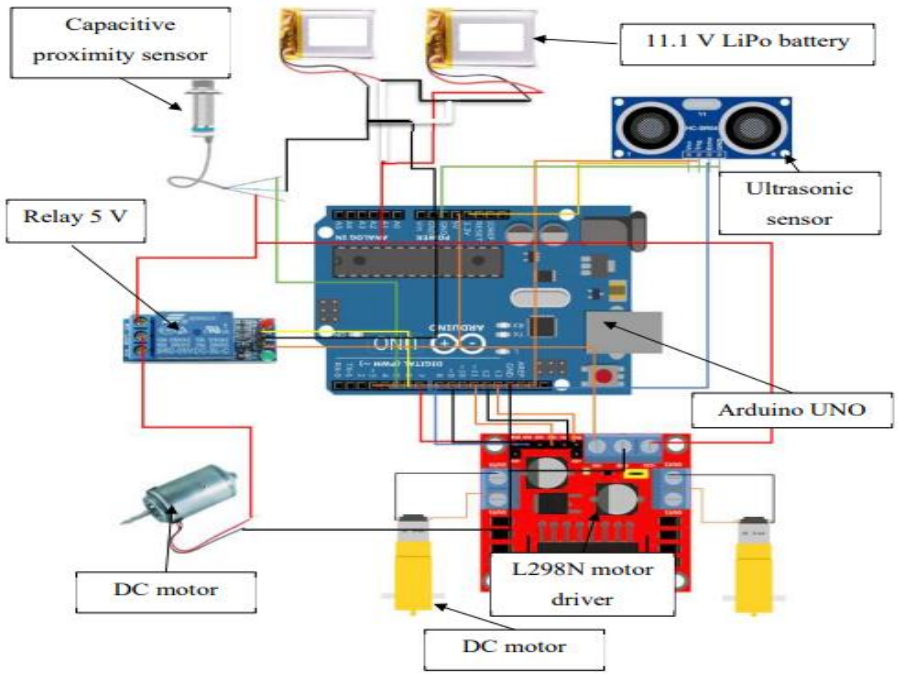

Figure 1: Design of electric circuit

Table 1: List of components

Component	Quantity	Description
11.1V LiPo battery	2	To supply power to the microcontroller, DC motor, ultrasonic sensor and capacitive proximity sensor
Ultrasonic sensor	1	To measure the distance between robot and solar panel
Arduino UNO	1	To control the overall cleaning process of the robot
L298N motor driver	1	Embedded with Arduino UNO to connect with the DC motor
DC motor	3	To rotate the nylon brush and move the robot
Capacitive proximity sensor	1	To detect any object that attached with the solar panel

Then, for the robot movement, the motor driver L298N and DC motor is power up by the battery. While the digital input and digital output pin of motor driver L298N connect with pin port in Arduino UNO to control the movement of DC motor as shown in Table 2. In Table 2, it shows the pin configuration of this electrical design. Based on the table, it shows the echo and trigger pin of ultrasonic sensor also relate to the Arduino Uno pin port to send and analyse the data for calculating the distance between the solar panel cleaning robot with the solar panel and to move the DC motor. Next, the input signal pin of capacitive proximity sensor has been connected with the pin port of Arduino UNO to analyse the data and send the signal to 5V relay to switch ON the DC motor to rotate the nylon brush if the sensor is trigger Figure 1.

Table 2: Pin configuration of electric circuit

Component	Arduino UNO pin	Module
Ultrasonic sensor	D3	Trigger pin
	D4	Echo pin
Motor driver L298N	D12	Positive side right motor
	D11	Negative side right motor
	D13	Input right motor
	D9	Positive side left motor
	D8	Negative side left motor
	D7	Input left motor
Capacitive proximity sensor	D5	Input signal

2.2 Mechanical Design

The mechanical design will be divided into three phase which are sensor placement, cleaning mechanism and wheels and motor placement. The ideal placement for the ultrasonic sensor is at the front of the robot. The purpose of install it front of the robot because the ultrasonic sensor needs to calculate the distance of the solar panel cleaning robot with the solar panel to avoid the robot from falling. When the distance between the robot and solar panel is above 2.5 cm, the sensor sends the data to the microcontroller to give the instruction for the DC motor on the right side to stop and the robot will rotate to right. Then, the capacitive proximity sensor has been placed in the middle between the ultrasonic sensor and DC motor for rotate the nylon brush as shown in Figure 2.

Next, for the second phase which is cleaning mechanism, the ideal placement for the nylon brush is below the robot body and after the capacitive proximity sensor and relate to DC motor. The brush turns ON if the capacitive proximity sensor detects an object. The brush remains OFF if the sensor did not detect any object. While, the microfiber brush is the fix brush that be located below the robot and at the behind for wipe any dirt as shown in Figure 2. Lastly, for the wheels and motor placement, two DC motor that connected with the wheels will attached to the side of the robot at the behind as shown Figure 3. While, other two wheels is place at front of the robot. The dimension of this robot is 26 cm for the length and the width is 15 cm.

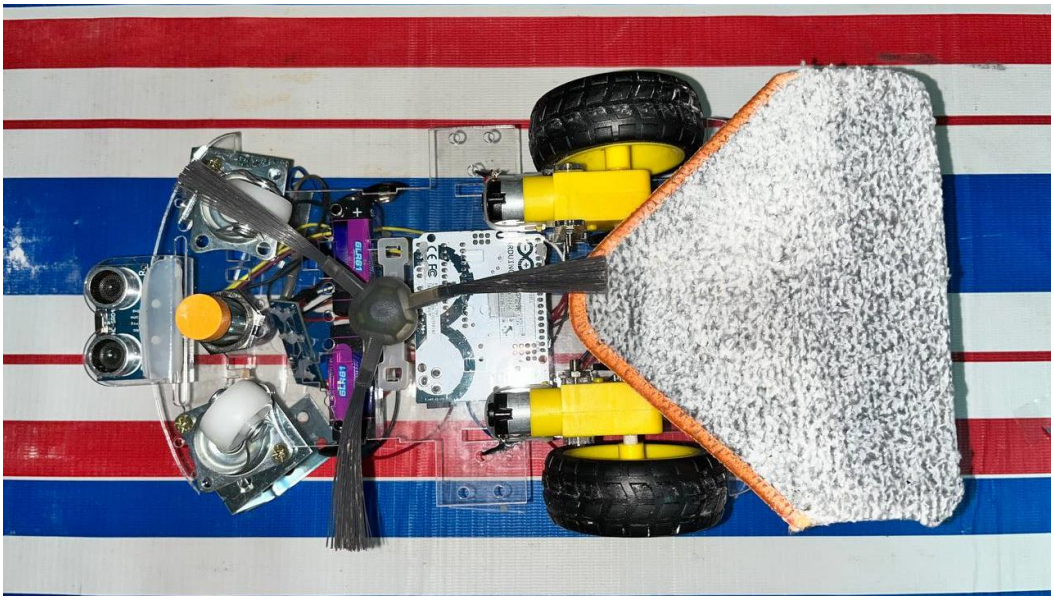

Figure 2: Bottom view of the prototype

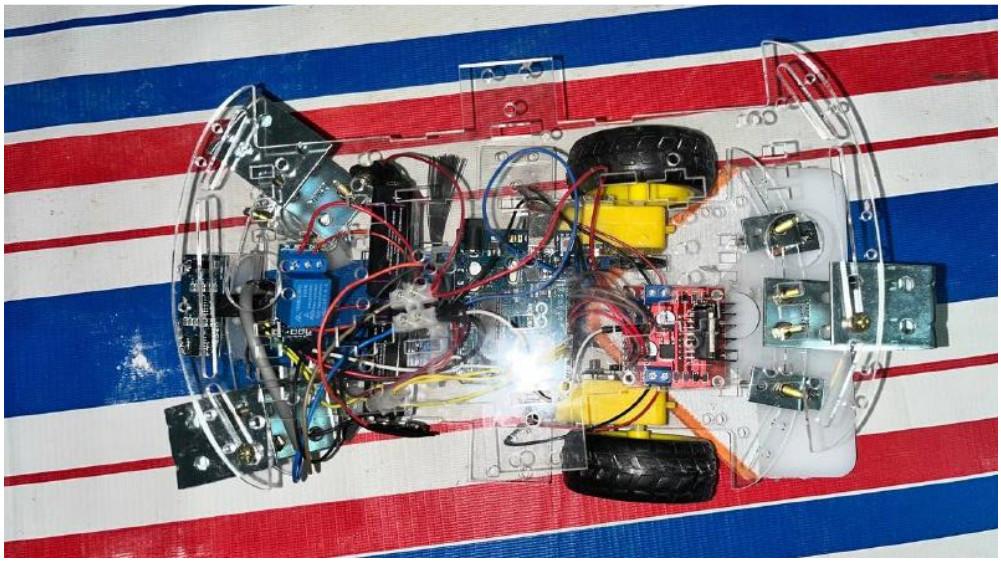

Figure 3: Top view of the prototype

2.3 Proposed Algorithm of Solar Panel Cleaning Robot

In Figure 4, it shows the block diagram of the proposed solar panel cleaning robot. Based on the Figure 4, the solar panel cleaning robot consists of two subsystems. The first subsystem is the cleaning system which is the capacitive proximity sensor will detect any object on the surface of solar panel such as bird pooping. Then, the signal from the sensor will send to the microcontroller to process the signal and give the signal to motor driver to rotate the nylon brush for the cleaning purpose.

Then, the second subsystem is the movement of solar panel cleaning robot system. In this system, the signal of ultrasonic sensor will send to microcontroller to process the signal and give the instruction to the motor driver either to stop when reach the edge of solar panel and change the direction of the robot or move forward until reach the edge of solar panel.

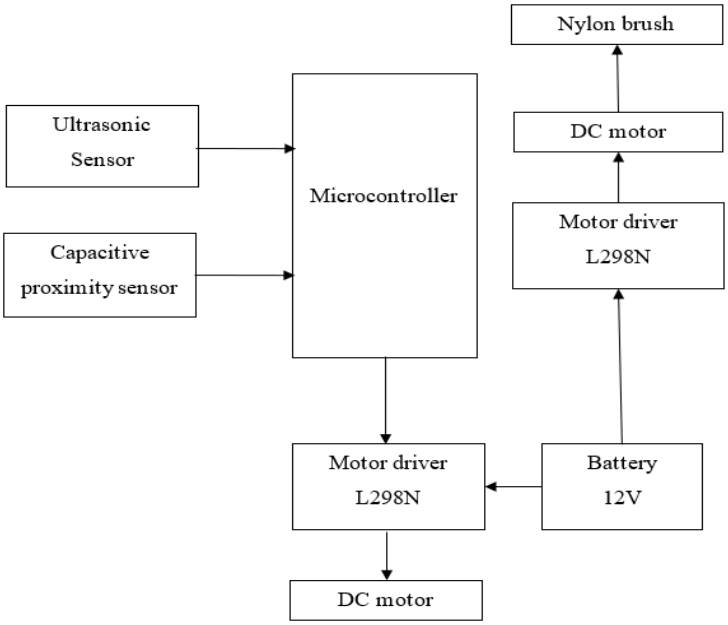

Figure 4: Block diagram of proposed system for solar panel cleaning robot

In this project, the programming system is written and compiled by using Arduino IDE. The function of the Arduino IDE software is to receive and process the control signal from the sensor and send the processed signal to the microcontroller which is Arduino to control the cleaning system and the movement of solar panel cleaning robot. Figure 5 shows the flowchart of cleaning system algorithm. Based on the Figure 5, it shows when the capacitive proximity sensor detects an object, the nylon brush be turn ON. While, if the sensor did not detect any object the nylon brush will remain OFF.

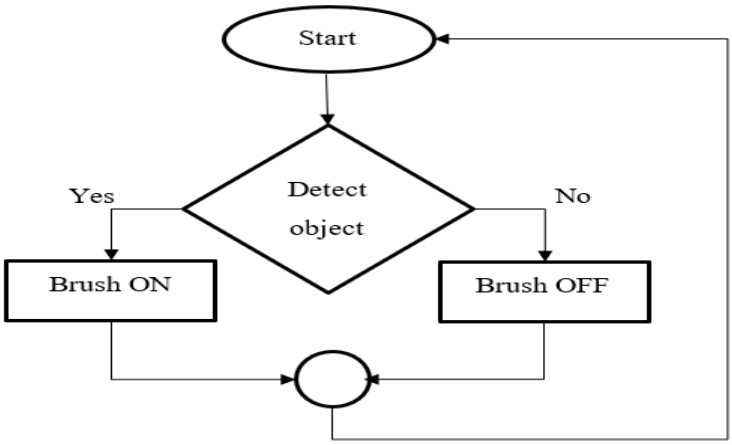

Figure 5: Flowchart of cleaning system algorithm

Figure 6 shows the flowchart of this robot movement where the system comprises connection of ultrasonic sensor, Arduino Uno, DC motor and motor driver L298N. The function of ultrasonic sensor is used to measure the distance between the solar panel cleaning robot with the edge of the solar panel. Therefore, if the ultrasonic sensor read the distance between the edge of solar panel and robot is below 2.5 cm the robot will move forward until the ultrasonic sensor detect the distance of the robot with the edge of solar panel is 2.5 cm and above, the robot will rotate to the right of solar panel. If the ultrasonic sensor calculates the distance of solar panel and robot 2.5 cm and above, but the Arduino UNO did not

analyse it as state in the coding to stop the right side of DC motor, therefore the robot will fall from the solar panel.

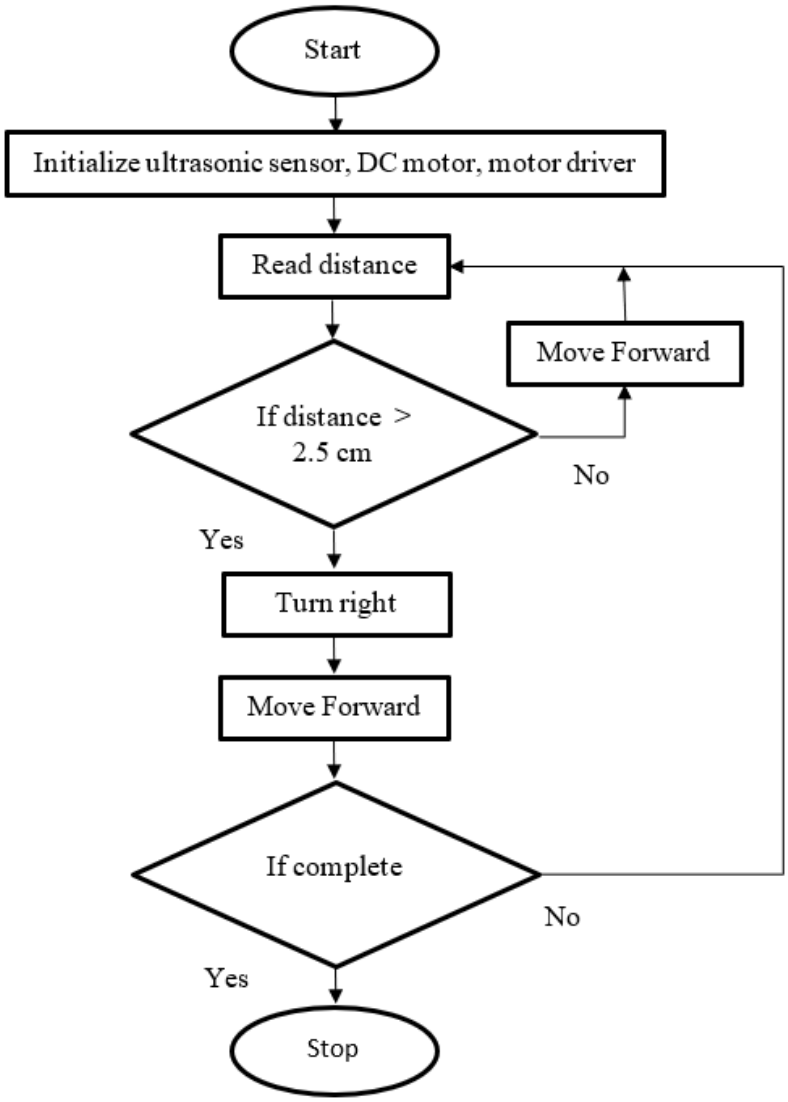

Figure 6: Flowchart of movement for solar panel cleaning robot

3. Results and Discussion

The performance of solar panel cleaning robot will be tested in two phase which is the first phase is testing the movement of solar panel cleaning robot. Then, in the second phase is testing the robot in cleaning the solar panel with two different conditions. In this testing, the table was used as the solar panel. Meanwhile, the powder was used represented as dust and the shredded paper was used as leaves.

3.1 Testing the movement of robots.

In order to test the movement of solar panel cleaning robot, the ultrasonic sensor is tested for it accuracy and the result is recorded as shown in Table 3. Based on the table, the results show when the distance is below 2.5 cm which are between 0 cm to 2 cm, the DC motor on the left and right side is ON therefore the robot will move forward. While, if the distance is above 2.5cm which are between 3 cm to 5 cm, the DC motor on the right side is turn OFF meanwhile, the DC motor on the left side is remain ON. Hence, the robot will turn to the right.

Table 3: Result of ultrasonic sensor testing

Recorded distance (cm)	DC motor (Right)	DC motor (Left)	Robot movement
0	ON	ON	Forward
1	ON	ON	Forward
2	ON	ON	Forward
3	OFF	ON	Turn right
4	OFF	ON	Turn right
5	OFF	ON	Turn right

Therefore, the solar panel cleaning robot able to move around the solar panel as the proposed as shown in Figure 7 where the robot turn to the right if the distance of the robot with the table is 2.5cm and above. While, if the distance of the robot and the table is below 2.5 cm, the robot will remain move straight.

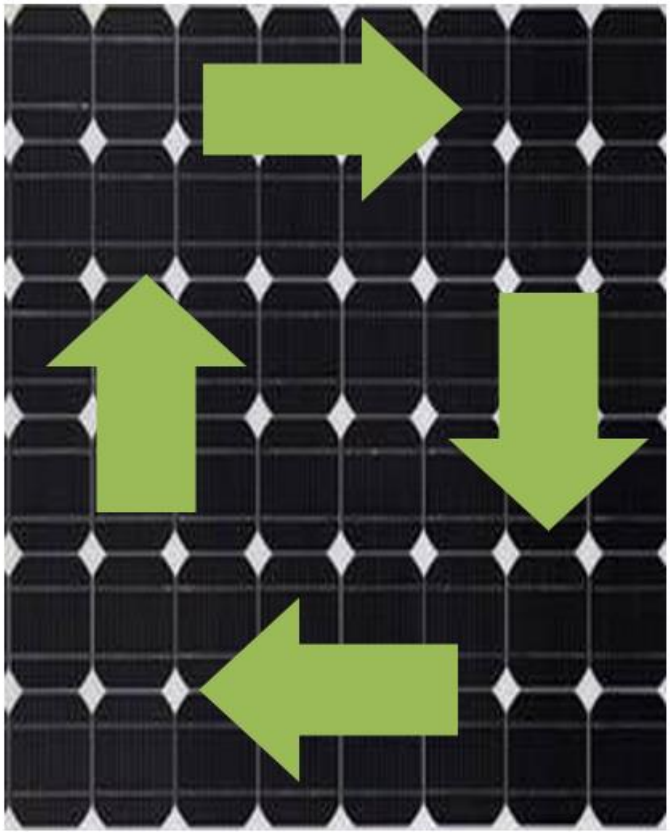

Figure 7: The movement of solar panel cleaning robot

3.2 Testing the Robot in Cleaning the Solar Panel

The performance of solar panel cleaning robot in cleaning the solar panel be tested by two conditions. In first condition, the robot be tested to clean the powder on the table. In this condition the microfiber brush was successfully clean up the powder on the surface on the table. Besides that, during cleaning the powder, the DC motor that connect with the nylon brush is not rotate due to the capacitive proximity sensor is not trigger. It is because the sensor did not detect any object.

Then, for the second condition, the robot be tested to clean the shredded paper on the table. Based on the Table 4, during this condition, the capacitive proximity sensor able to detect the shredded paper.

Therefore, the DC motor that connect with the nylon brush is turn ON to sweep the shredded paper on the table to the side as shown in the Figure 8.

Table 4: Testing performance of solar panel cleaning robot

Criteria	Powder	Shredded paper
Capacitive proximity sensor	OFF	ON
Nylon brush	OFF	ON
Cleanliness level	Good	Good

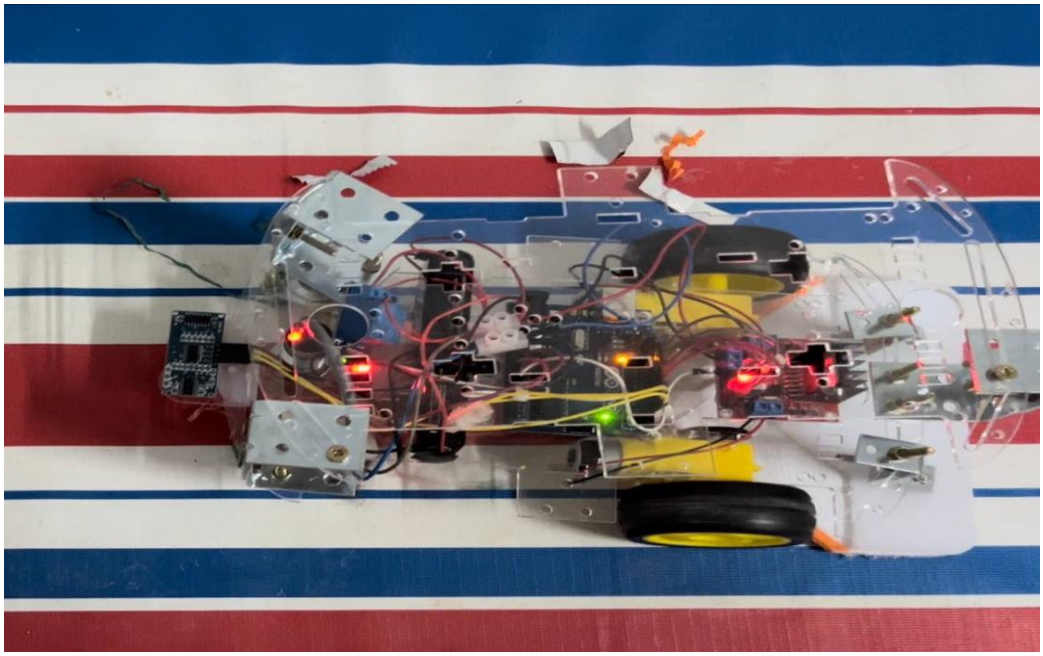

Figure 8: Solar panel cleaning robot clean the shredded paper

4. Conclusion

In conclusion, the solar panel cleaning robot is successfully developed according to the proposed design and system. In addition, by using microfiber brush, the robot is able to clean up the solar panel that is affected by the dust while by using the nylon brush, it is able to sweep the shredded paper that represents a leaf. However, there is an obvious limitation in this system, which is when the robot sweeps the shredded paper, the shredded paper only goes to the side. Therefore, further research with suction systems can be added to this system to improve the robot system in cleaning the solar panel.

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