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Smart Robot Cleaner Using Internet of Things

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ABSTRACT

The most dreaded chore is cleaning the house where it is at the top of the list for many people. Cleaning the house is time-consuming and must be carried out continuously. This study aims to design an autonomous robotic cleaner for a self-driving robot that automatically cleans the floor. The Smart Robot Cleaner is proposed and established using the Internet of Things (IoT). The robot is equipped with microfiber cleaning, a water tank, a water pump, ultrasonic sensors, a DC motor, a hose tube, and a wheel. The Arduino Uno is used as the main component and is connected with an ultrasonic sensor to detect any object and obstacles. To allow Internet of Things functions in this robot, the Bluetooth module is used as a command from the smartphone to control the movement. The experimental results showed that the performance of the proposed smart robot cleaner is able to clean various dirt, such as water, milk, and sauce. The robot can be manually and automatically controlled via smartphone.

1. Introduction

The advent of robots has revolutionized various industries, providing programmable machines capable of executing intricate tasks with minimal human intervention. Among these applications, the deployment of robots in household settings is increasingly gaining popularity [1]. Notably, the rise of domestic robots, with robot vacuum cleaners being at the forefront, has become a prominent trend [2]. However, it's crucial to recognize that only a fraction of the vast array of existing robots is designed for mundane household chores, and within this category, the significance of cleaning and mopping robots becomes apparent [3]. These robots, characterized by their simplicity and automation through predefined algorithms, are programmed to efficiently clean designated areas, aiming to reduce human involvement while expediting the cleaning process [4].

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The market boasts several successful products, such as iRobot Roomba, Rrimin Smart Vacuum Cleaners, and Exilian Ready Maid Robotic Vacuum Cleaner [5]. Each product comes with its own set of advantages and disadvantages, but a common challenge is the relatively high cost associated with these technologies [6]. Furthermore, their effectiveness tends to vary, with better performance on tile surfaces compared to wooden floors, and optimal functionality often requiring investment in high-end versions [7].

Daily routines, including floor cleaning, are integral tasks that demand attention not only in homes but also in offices and various other buildings. Traditional cleaning methods, like manually scrubbing floors, are not only time-consuming but also labour-intensive, challenging the capacity of janitorial staff to keep up with the demand. Recognizing this challenge, researchers and developers have explored various robot technologies to facilitate automatic cleaning [8–14]. Studies indicate that robots can effectively replace or complement human activities, particularly in processes where they can be remotely or automatically controlled.

This research contributes to the evolution of automated cleaning solutions by presenting the design of an autonomous robotic cleaner for self-driving robots, leveraging the power of Internet of Things (IoT) technology [15]. The robot's feature set includes microfiber cleaning capabilities, a water tank, a water pump, ultrasonic sensors, a DC motor, a hose tube, and a wheel. The Arduino Uno serves as the brain of the system, connected to an ultrasonic sensor responsible for object and obstacle detection. Noteworthy is the robot's versatility, offering users the option for both manual and automatic control via a smartphone through a Bluetooth module. Rigorous testing procedures have been employed to evaluate the smart robot cleaner's effectiveness in tackling various types of dirt, including water, milk, and sauce. The research also delves into the testing of the HC-SR04 ultrasonic sensor, a critical component of the robot cleaner, assessing its performance in range and angle detection. Recorded metrics from these tests affirm the robot's capability to successfully and satisfactorily clean the mentioned types of dirt, underscoring its potential in real-world applications.

2. Related Project

Some of the available products can be useful as reference in this research in identifying their advantages and disadvantages. Table 1 shows the comparison of popular brand robot cleaners in terms of function and technology used. These robot cleaners are intelligently programmed electronic devices that clean a specific area using a vacuum or mopping assembly. More advanced products available on the market can brush around sharp edges and corners, provide mopping for wet cleaning, and UV sterilisation instead of vacuuming. Taking into account the advantages and disadvantages of the robot mentioned above, a low-cost robot cleaner is proposed. In particular, the robot cleaner is introduced based on the Internet of things via Bluetooth is established.

Table 1
Related project

Types of robots	Type of use	Technology used	Pros	Cons
A Silver Trilobite Version 2.0 [16]	Vacuum cleaning	uses an ultrasonic sensor to detect obstacle	Thicker filter	Bigger & louder
Dyson Eye-360 [17]	Vacuum cleaning	360-degree panoramic vision camera	360-degree panoramic vision camera	expensive
Roomba [18]	Dry vacuum	IR, RF, and auto-charging mechanism	Easy to use, Easy to operate	Noisy
Scooba 380 [19]	Wet Washing of Floor	IR with virtual wall accessories	Clean up to 1,000 square feet with dry mop	Misses spot
Braava jet m6134 [20]	Floor mopping for hard surfaces/Dry clean	Floor mopping for hard surfaces/Dry clean	Easy to use, clean effectively	Noisy
Roomba i7 plus [21]	Vacuum cleaning	iAdapt 3.0 Navigation with patent VSLAM technology navigation	Better navigation	expensive
Neato xv-11 [22]	Vacuum cleaning	Laser range finder technology, SLAM	Auto docking and recharging	Dirt bin too small

3. Methodology

3.1 List of Components

Materials used in this project are Arduino Uno R3, Bluetooth Module HC-05, L293D Motor driver, SG90 RC Servo motor, 12V water pump and Ultrasonic sensor. Meanwhile, the software used in this project is Arduino IDE.

(a) Arduino Uno is chosen because the pins required in this project are not more than 13 digital PWM pins.
(b) HC-05 is a Bluetooth module designed to set up a wireless serial connection. It communicates via serial communication, making it simple to interface with a controller or a PC.
(c) L293D is a motor driver board that is used to power motors, as the name implies. A single L293D IC can control two DC motors at the same time, and the direction of these two motors can also be controlled independently.
(d) An ultrasonic sensor is used to detect the distance between an item and the sensor.
(e) SG90 RC is a servo motor that can be controlled by the knob on a rotating angle sensor and can rotate 180 degrees; SG90 RC is used to control the movement of the ultrasonic sensor depending on the detecting an obstacle.
(f) A direct current (DC) water pump is a machine that transports or pressurizes liquid. The coil and the commutator rotate when the water pump is on, but the magnetic steel and carbon brushes do not. The commutator and brushes that rotate with the motor change the direction of the coil's alternating current. The water pump motor gets a signal from the Arduino Uno to channel water from the 1.5L tank to the mop pad.
(g) 12V battery used to ensure all components have enough power to perform well

3.2 Arduino IDE

The software used to control the autonomous smart floor cleaning robot system is Arduino software (IDE) as seen in Figure 1.

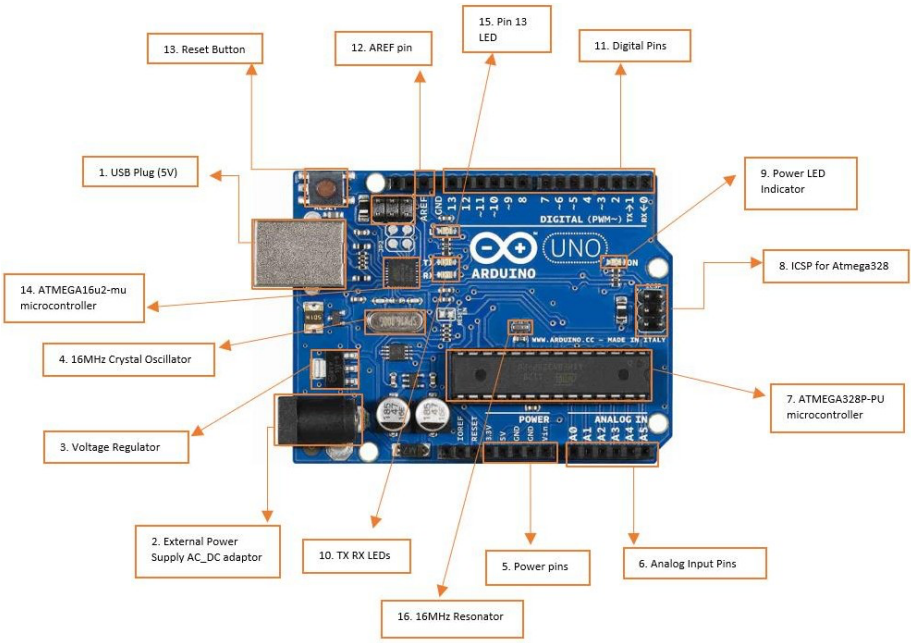


Fig. 1. Arduino Uno

Arduino software is open-source software that can easily be used to write the program and upload it to the Arduino board. Arduino 1.8.10 will be used to write a program, compile it, test it, and upload it to the microcontroller. The compiler converts the C language into machine code. The program created in the software will be transferred to the microcontroller via a USB cable. The data that are being uploaded to the Arduino Uno from the computer are in a parallel way. In addition, Arduino 1.8.10 was chosen because it is compatible with the microcontroller.

3.3 Experimental Set Up

Figure 2 describes the system integration for this project. The input of this project is the power source and Android. More specifically, Figure 3 illustrates the experimental set-up to operate the overall system of robot cleaner.

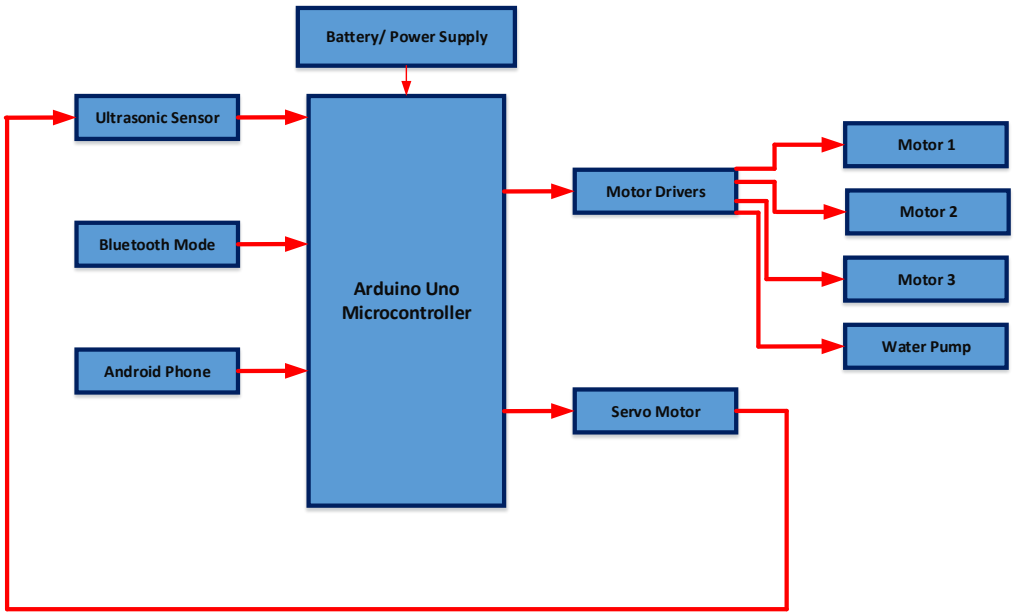


Fig. 2. System integration

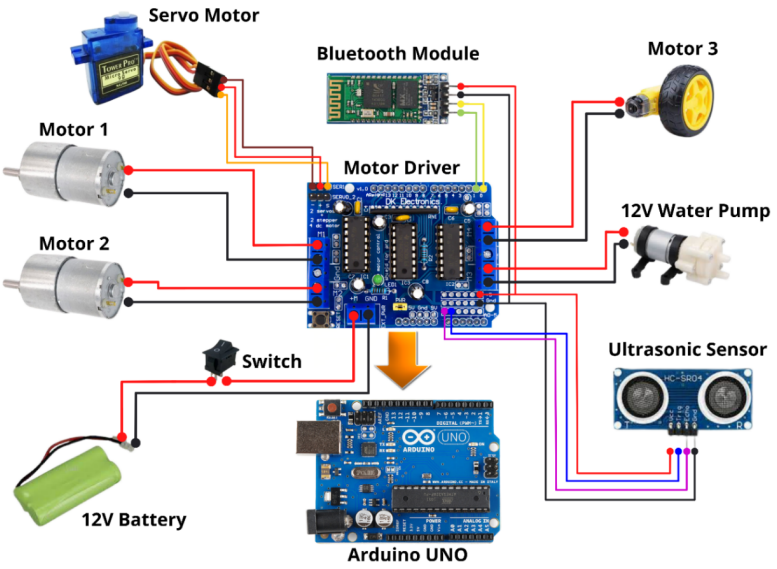


Fig. 3. Experimental set up

The robot cleaner needs to be powered on to activate it, and the user can decide to control manually or automatically. The motor will be automatically controlled by the motor driver according to the signal given by the pre-programmed path set in Arduino Uno. Usually, the desired command such as forward is set to start rotating the motor forward. Once the robot cleaner moves, the water pump starts to operate to allow water from the tank to flow into the hose tube for wet cleaning. During the cleaning process, ultrasonic sensors will detect obstacles and the new path will be set to avoid the collision. This process continues until the cleaning surface is clean. On the other hand, to manually control the robot cleaner, the Arduino Bluetooth RC car (i.e. android controlled) is used. In principle, four main components are required to control via android in this project, namely Arduino Uno board, L293D motor driver, HC-05 Bluetooth module and Bluetooth RC Car app. Once these four devices are integrated, in the Arduino Bluetooth car, the data is sent by the hc-05 mobile phone to the Bluetooth module, the manual mode is on. In this case, the Arduino makes decisions based on

the data received via Bluetooth. Through the Bluetooth RC Car app, the user can use the touch feedback to provide any instruction for different directions.

3.4 Coding

The following coding, as shown in Figure 4 is developed to perform the smart robot cleaner. In principle, the code is developed to allow the robot to move forward, backward, right, and left.

```
void Obstacle() {

//gets the ultrasonic sensor reading and puts it into the variable.
  distance = ultrasonic();

//then, these values are checked using the IF condition.
//If the value is less than or equal to 12,
//the robot is stopped and the servo motor rotate left and right.
// Also, gets both side distance.
  if (distance <= 12) {
    Stop();
    backward();
    delay(100);
    Stop();
    L = leftsee();
    servo.write(spoint);
    delay(800);
    R = rightsee();
    servo.write(spoint);

//After, if the left side distance less than the right side distance. The robot turns right.
    if (L < R) {
      right();
      delay(500);
      Stop();
      delay(200);

//After, if the left side distance more than the right side distance. The robot turns left.
    } else if (L > R) {
      left();
      delay(500);
      Stop();
      delay(200);
    }

//Otherwise, the robot moves forward.
  } else {
    forward();
  }
}
```

Fig. 4. Coding for cleaning movement and avoid obstacles

4. Results and Discussion

4.1 Prototype

The porotype of the robot cleaner is shown in Figure 5. The low-cost cleaner robot consists of 1L water tank, ultrasonic sensors, on/off switch button, electronic compartment, microfiber cleaning pad, hose tube, DC motor, wheels and water pump. In general, the working principle of the robot is simple, where the robot moves forward once the switch button is on. Then, it will avoid collision with the obstacles by turning left and right. The robot will stop either by setting the operating period or immediately switch off the button.

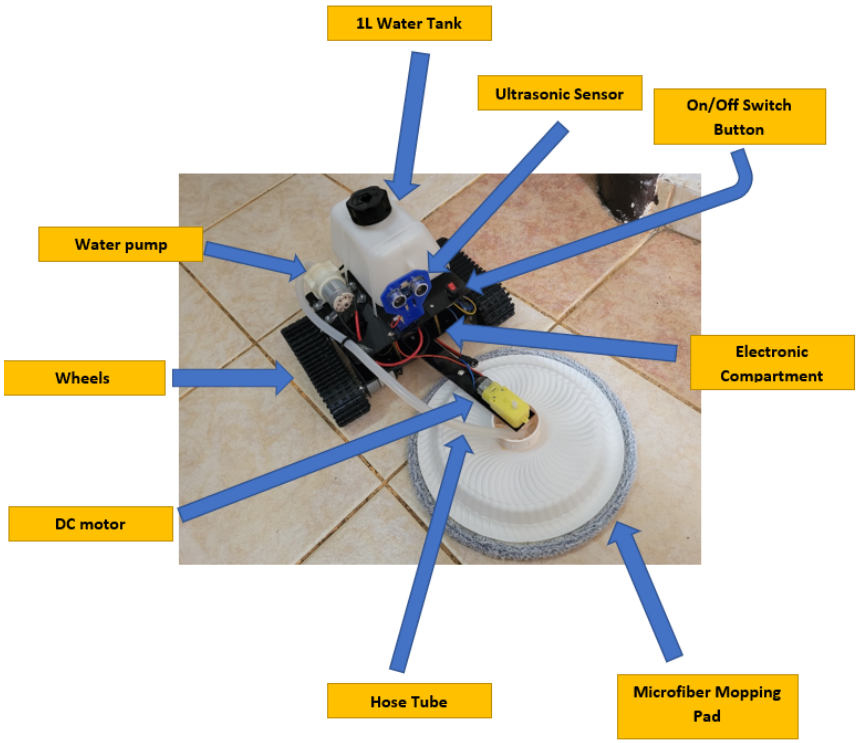
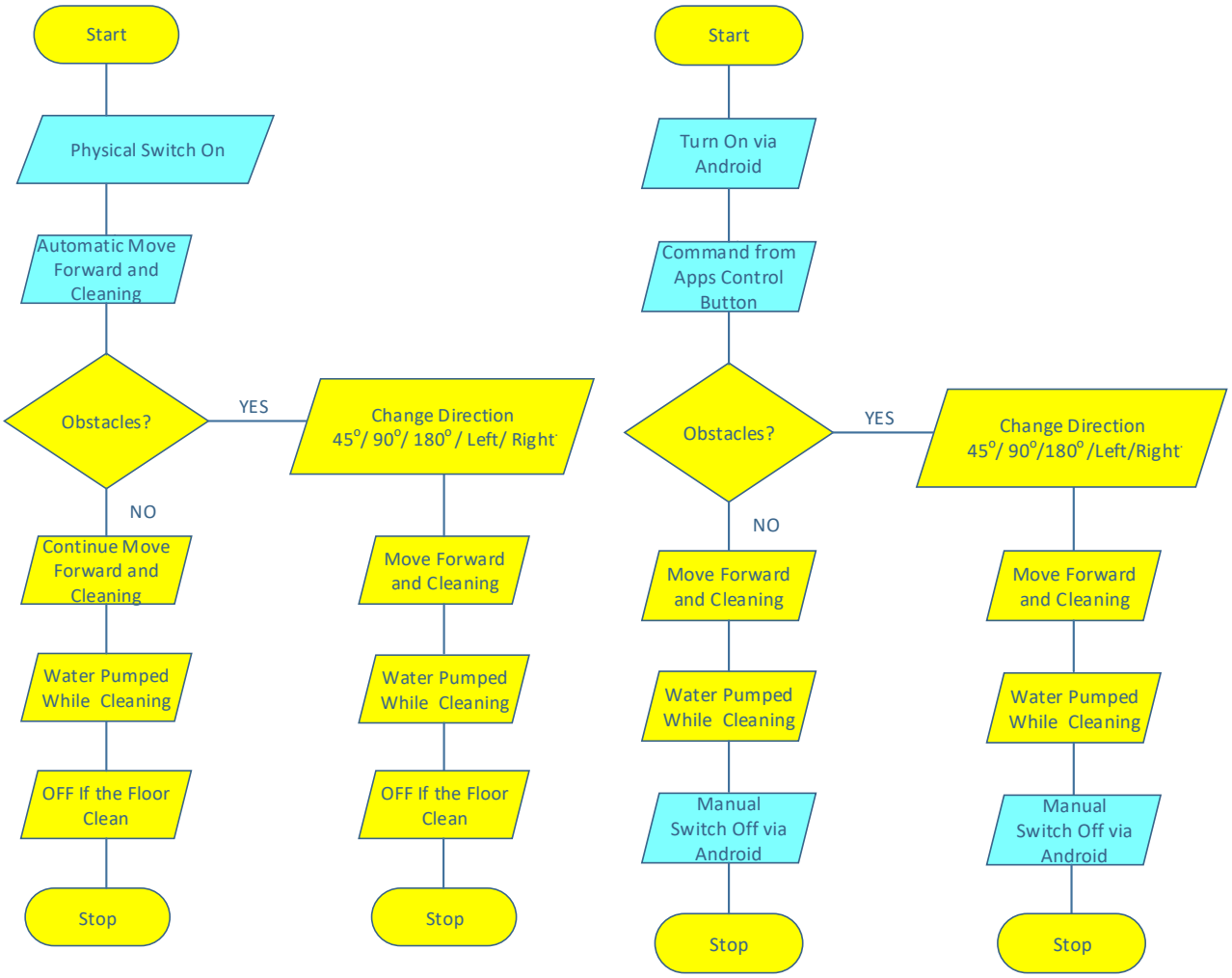


Fig. 5. Prototype of the Robot Cleaner

4.2 Operating System

As mentioned above, the user can choose to operate the robot automatically or manually. The flow of the automatic and manual working process is shown in Figure 6. When choosing an automatic controller, the Arduino output signal is connected to the motor driver, the water pump, and the servo motor. The output signal from the motor drivers will be sent to the motor. The motor will be controlled by the motor driver according to the signal that is given by the main controller, which is Arduino Uno that is pre-programmed for the path. After finishing the setup, the motor will start to rotate to move forward according to the command, or it will run automatically. The water pump works as a pump. The water flows from the tank for wet mopping. Sensors will work while the robot is moving. The sensors will sense when there is an obstacle in front and the sensors will send the feedback to the main controller to rearrange the pathway.

On the other hand, to manually run the robot, the motor will be controlled by the motor driver according to the signal given by the main controller, which is an android application that is pre-programmed for the path. When the user receives commands from the transmitter app, the relay acts as a switch. The arm utilized in this example is made up of two dc motors, both of which are used to completely rotate the mopping pad. L239D drivers are used to drive dc motors, such as forward and backward. Note that a Bluetooth module must be used within a certain range to operate the robot using a mobile phone application.



(a) Automatic operational flow (b) Manual operational flow

Fig. 6. The process flow of automatic versus manual operating system

4.3 Sensor Performance

The HC-SR04 ultrasonic sensor has been tested for its range and angle detection to identify its limit area. The range distance of the ultrasonic sensor is from 2 to 50 cm.

Table 2 shows that the object has been detected in different ranges. The data of the linear relationships between voltage and distance is recorded as shown in Figure 7.

Table 2
Voltage versus Distance

Detected Ranging Distance (cm)	Voltage (V)
0-15	0
16-29	0.1
30-43	0.2
44-53	0.3
54-74	0.4

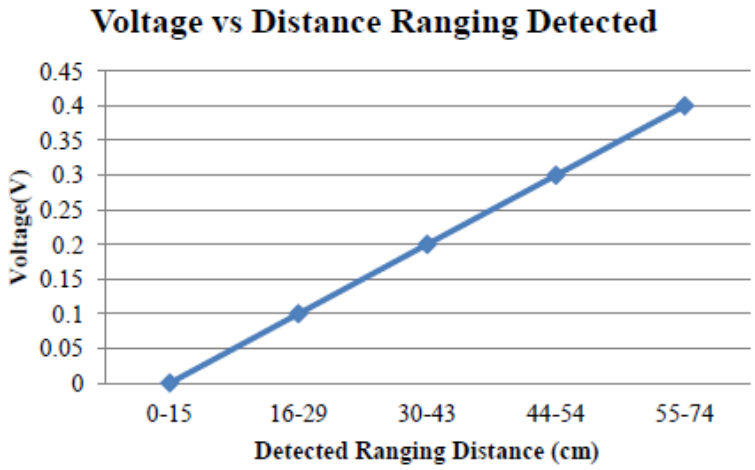


Fig. 7. The linear relationships between voltage and distance

4.4 Bluetooth Performance

The Bluetooth module HC-05 is used in this project, connecting the system to the mobile phone as shown in Figure 8. Within a short distance, it can exchange data from devices such as mobile devices and building personal area networks (PANs). In a range of about 9 meters, this Bluetooth can communicate with the microcontroller via the serial UART bus. Figure 8 illustrates the connection between Bluetooth and the Microcontroller.

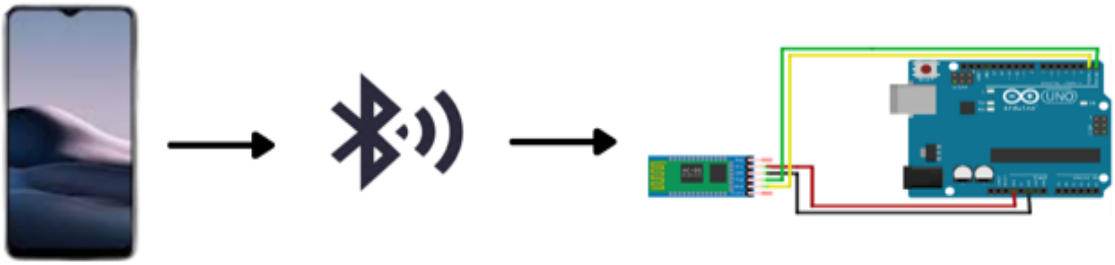
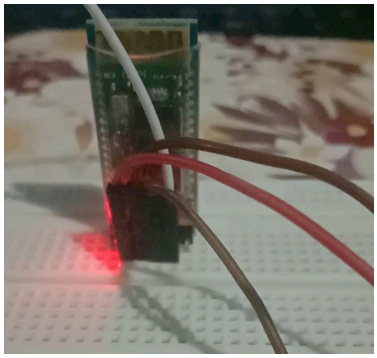
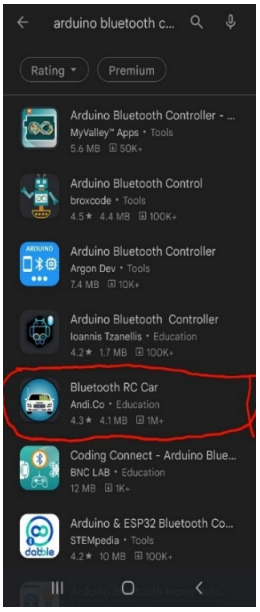


Fig. 8. Connection between Bluetooth and the Microcontroller

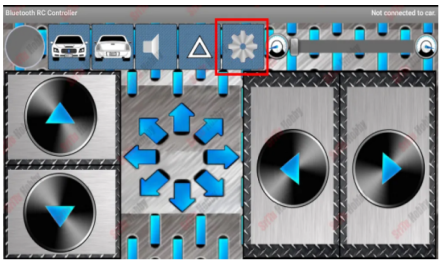
Figure 9(a) shows that Bluetooth is activated after the pin connects to the right connection and the red light illuminates to show that the Bluetooth module is On. Then, Bluetooth on the mobile will search for other device for connections. In this case, the Bluetooth control car applications appear on the mobile screen as shown in Figure 9(b). Note that the Bluetooth controlled car is a robot which is built using an Atmega8 microcontroller in which serial communication is achieved via Bluetooth. The car in this case is the robot cleaner. Once the 'Connect to the car' indicator is clicked as shown in Figure 9(c), the HC-05 pair device appeared on the screen as shown in Figure 9(d). Under this condition, the green bulb as shown in Figure 9(e) is on and the robot cleaner is ready to be remotely controlled. Here, buttons such as left, right, forward, and back can be used to control the robot cleaner.



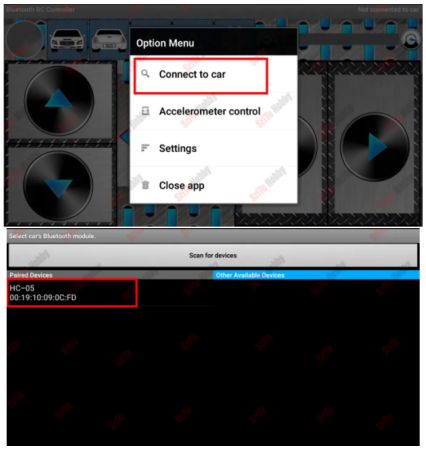
(a) Bluetooth Connected



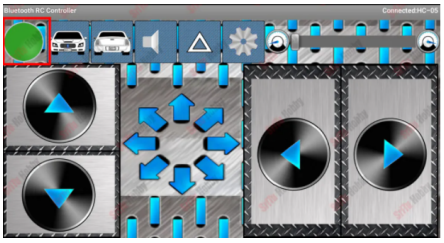
(b) Apps Bluetooth Control



(c) Arduino Bluetooth RC Car Apps



(d) Connect Apps to Bluetooth module

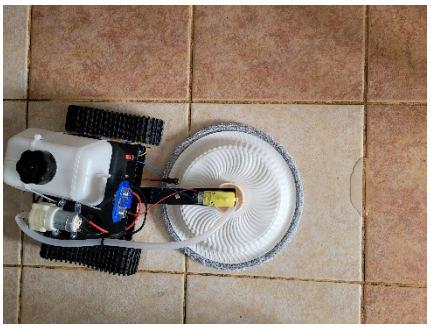


(e) Green bulb on

Fig. 9. Setting Bluetooth connection through Android

4.5 Robot Cleaner Performance

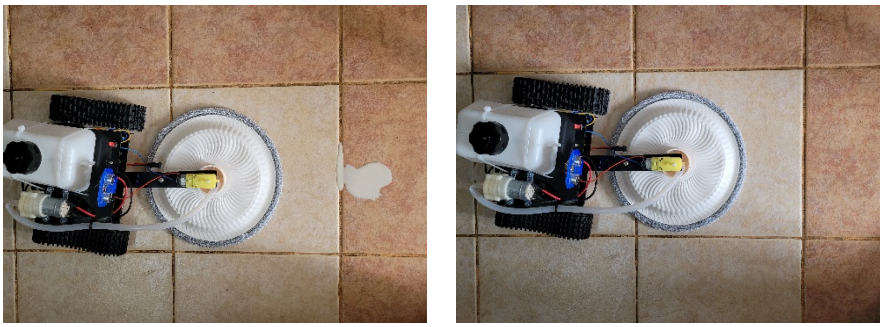
The performance of the robot cleaner is tested, and the results are recorded. Three different dirt are considered, namely water, milk, and sauce. Figure 10, Figure 11 and Figure 12 record the performance of the robot cleaner for water, milk, and sauce, respectively.



(a) Before cleaning water

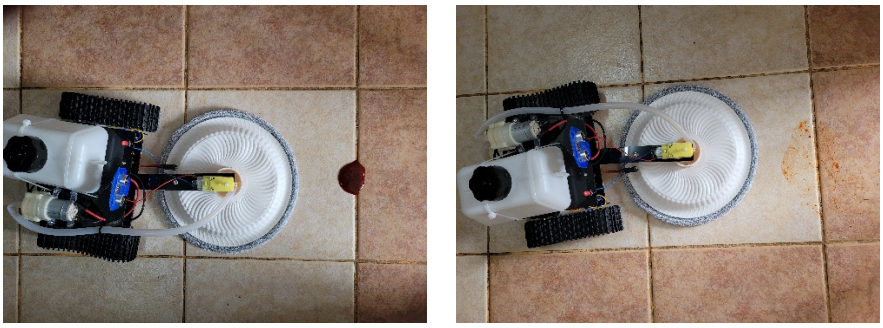
(b) After cleaning water

Fig. 10. Robot Performance for Cleaning Water



(a) Before cleaning milk (b) After cleaning milk

Fig. 11. Robot Performance for Cleaning Milk



(a) Before cleaning sauce (b) After cleaning sauce

Fig. 12. Robot Performance for Cleaning Sauce

It is found that the robot is able to clean the mentioned dirt successfully and satisfactorily. Through observation, the floor looks dirty before cleaning and becomes clear after the cleaning process.

5. Conclusions

The Smart Robot Cleaner has been successfully developed and operated based on the Internet of Things. More specifically, a smartphone is used as a remote mobile that runs the robot cleaner using the Android application and the Bluetooth module to send instructions to the microcontroller. The instructions from the Bluetooth module microcontroller play an important role in sending its output to the motor driver. Then, the motor of the robot cleaner rotates from one location to another according to this input command. The user can control the movement of the robot either forward, left, right, or backward. Obstacle detection and collision avoidance have been successfully demonstrated. However, the robot can still be improved, such as employing the tilt sensor to detect slop. Moreover, the robot size can also be reduced to work in a small and unreachable area.

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