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Design and Implementation of Vacuum Cleaner Robot Using Arduino and Smartphone

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Abstract: The purpose of this study is to discuss development of a vacuum cleaner robot using an Arduino with an Android smartphone. Vacuum cleaner robot is designed to make cleaning process become easier rather than by using a manual vacuum. The main idea is primarily by having the sensor to sense any object like wall and dust. Then send the output data to an Arduino that will control the robot vacuum movement. To facilitate targeted functions interactivity in conjunction with high quality sensors play essential roles. In this study, an intelligent interface robotic vacuum cleaner is developed. By using HC-06 Bluetooth module, the user can remotely manipulate its movement with Android smartphone. There are two kinds of function which are an automatic vacuum cleaning mode and manually controlled cleaning modes are developed. An automatic vacuum mode is operated when user can just turn on the robot vacuum to clean without having to monitor the robot. Meanwhile, for the manually controlled cleaning mode operation, the user can control the movement of the robot vacuum by using an Android smartphone through android application. Consequently, a prototype robot has been manufactured and tested in a laboratory.

Key words: Vacuum cleaner robot, obstacle avoidance, smartphone, Bluetooth, movement, facilitate

INTRODUCTION

There have been a number of development of robotic has been done in various application such as in sport, rehabilitation, manufacturing and others. Maximize the utilization of robot to fulfill human requirement is a part of life (Kanjanawanishkul, 2015; Annuar *et al*., 2016; Taher *et al*., 2016; Zulkefi *et al*., 2015). Furthermore, robots are developed as home appliances recently as there are a huge demand on the individuals. As the technology growth, home mechanical machine technology exploration is getting to be dynamic like never before. For instance, a big vacuum cleaning machine is available for domestic and industrial utilization but their operations are non-type and only some specific function of cleaning can be performed.

Vacuum cleaner robot is designed to improve cleaning process become easier for a human task that will assist people at home who are too busy for daily or weekly floor cleaning and particularly for the elderly who does not have the strength to clean up the house. Currently, various robotic vacuum cleaners have been presented. However, they have focused on ground cleaning and lack interactivity between the robot and the user. In order to improve interactivity between robot and user, an intelligent robot in conjunction with a Bluetooth module has been developed.

According to Nikita Prashar *et al*., microcontroller is used in a vacuum cleaner robot to detect obstacles and manipulates its direction as per the inputs. There are some modification have been made to robot vacuum in order to improve practicability as well as ease human task. Another research from microcontroller is used in a robo-cleaner to detect obstacle and employs its direction. In this study, there are four sensor used which are one for front and others for left, right and backside, so, robot can clean the whole area. Besides, the wheels of robot are controlled by motor-driver in collision condition. In order to suck dirt, a vacuum cleaner is implemented within system.

A home-based assistive robotic for the elderly and disable with a huge improvement and advances in terms

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of computing, communication that relate to robotic technologies have been made in a way to produce a cheaper and more capable robot. This study proposed to utilize a floor cleaning robot and mobility and a vision assistance robot in a form of rollover walker. Besides, the open source software of the Robot Operating System (ROS) is used to accelerate the design process (Benavidez *et al*., 2015).

In order to compute efficient path for robotic cleaner, Hess *et al*. (2013) presents a novel approach on modeling and estimating the dynamics of dirt. Poisson processes are used to estimate the dirt distribution to allow an effective estimation of the dynamics of the generation of the dirt. The cleaning efficiency is proposed through experiment carried out with a modified iRobot Roomba vacuum cleaner. Mamrot *et al*. (2014) states that the requirements of the product system can be prioritized by analyzing the most frequent and the most important. In order to design an enhanced product, an over-design of robot vacuum cleaner is prevented but the use of a high quality product is supported.

Mishra *et al*. (2015) carried out an experiment proven that Bluetooth helps human to save time and energy in carrying out daily work but Bluetooth also have limitations in terms of range and battery usage. In the research from Nadvornik and Smutny (2014) on the design and application of the mobile application for Android operating system highlight that instead of using GSM cellular phone network data from another device, it can also be exchanged through Bluetooth and Wi-Fi wireless technology.

Furthermore, obstacle avoidance is crucial task in the field of robotic in order to reach a destination without collision. Zohaib *et al*. (2013) proposed several algorithms for obstacle avoidance having drawbacks and advantages. In this study, different algorithms for robot navigation with obstacle avoidance have been compared in terms of characteristic, advantages and disadvantages in order to choose an efficient algorithm.

Now a days, there are many researches on obstacle avoidance of a mobile robot. Li and Choi (2013) designed a fuzzy logic system and proposed an obstacle avoidance algorithm for a path planning in an unknown environment using an ultrasonic sensor. Besides, a fuzzy logic system implements an angular velocity control left and right wheels. As a result, the proposed fuzzy logic system showed a good performance with small control rules and fast travelling time.

Lastly, robots have becoming necessary assistants in human life. In this modern era, everyone holds a smartphone, tablet PC or laptop. In research from Kuo *et al*. (2014) showed that a conventional cleaning robot can be integrated with networks, vision and smartphones. Furthermore, it can be seen that autonomous tracking, remote monitoring and controlling through internet and Wi-Fi can be performed in the house cleaning task.

This study discusses a combination of software and hardware. The hardware of vacuum cleaner robot consists of the Arduino UNO, analog distance sensor, the motor-driver (L298N), the HC-06 Bluetooth module, the vacuum, the power distribution and also the chassis for the robot. As for the software Arduino IDE is used to write the programming in order to give command to the robot to run, SolidWorks used to design the chassis of the vacuum cleaner robot and Bluetooth serial controller is an Android application for interfacing Arduino and Android smartphone. By using a Bluetooth module, not only the vacuuming function be performed automatically but it can also be controlled manually by Android smartphone. So, the robot can efficiently clean up the entire area.

MATERIALS AND METHODS

Based on Fig. 1, the block diagram shows how the overall system operate input and outputs of various stages. First, it consists of Arduino microcontroller being the main part that contains the overall operation of the system. Then for the inputs there is analog distance sensor as obstacle sensor that is used to avoid obstacle and HC-06 Bluetooth module to provide a wireless communication link between the Arduino and Android smartphone. As for the output, motor-driver (L298N) allows Arduino to drive DC geared motor by controlling the speed and direction and 3 V mini vacuum for suction of dust.

Arduino IDE is the software that is plays role to be a place for the programming command written to send to the robot. Besides, the SolidWorks is software which is can be used to draw the part of the robot body in 3 dimensional. After that the draw of the robot body can be printed by using the 3D printer. The software used gives a lot of contribution to implement into hardware development. The components were identified to make

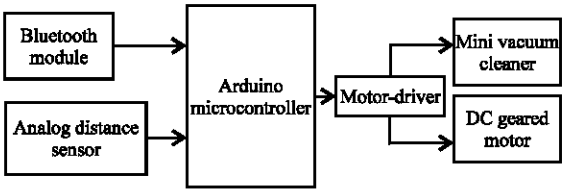

Fig. 1: Block diagram of vacuum cleaner robot

sure it is suitable and fit in the project research. Next, the hardware part and software part is test and troubleshoots to see if it is working or not.

As indicated in Fig. 2, Bluetooth device is interfaced to the control unit on the robot for sensing the signals transmitted by android application. This data is conveyed to the control unit which moves the robot as desired. Figure 3 shows the sample design for this robot.

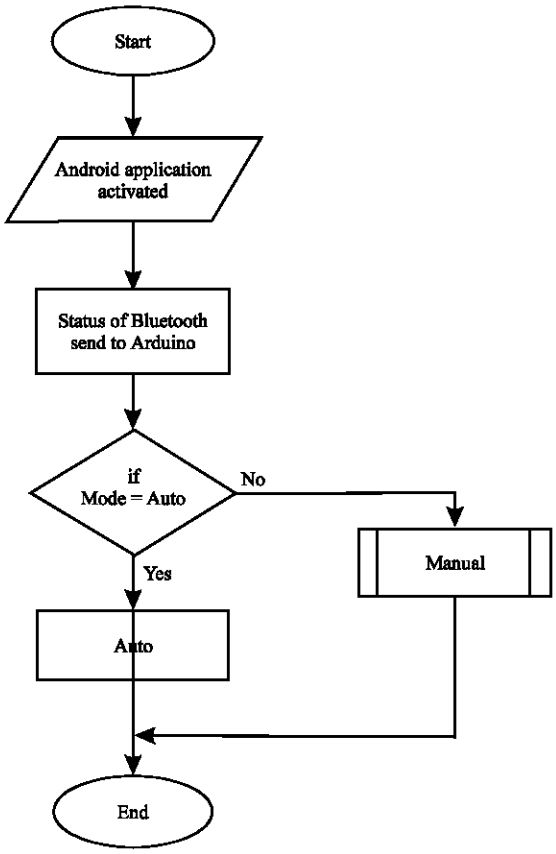

Fig. 2: The robot vacuum cleaner operation

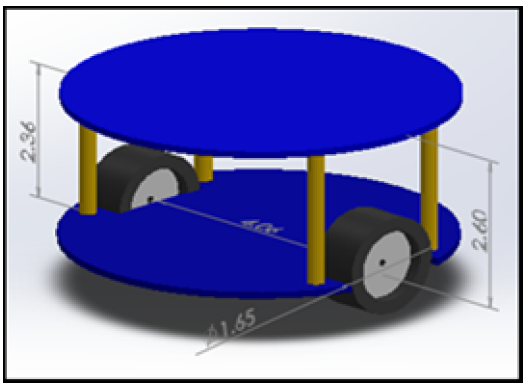

Fig. 3: Assemble all the part

An Atmel 328 microcontroller is used as control device. Remote operation is achieved by Android smartphone with Android OS, upon a GUI (Graphical User Interface) based touch screen operation. There are two function modes which are auto and manual mode. If user chooses the Auto Mode the vacuum cleaner robot will automatically activated for 20 min. As for the manual mode the user can remotely control the movement of the vacuum cleaner robot through android application in the smartphone.

RESULTS AND DISCUSSION

In this study, it is explained the results of research and at the same time is given the comprehensive discussion. The results of this development which are the outcomes from interface design will be discussed. The analysis will be divided into two parts which are the analysis of software part and the analysis of hardware part.

Interface design: Figure 4 shows the design of the built button by using Bluetooth Serial Controller programmer. The event for button is forward, backward, left and right. For example, backward event is used on a button, so that, when the button is pressed the backward event of a button is running.

The button will execute when the button backward event is held down and the button upward event will execute only when the user release the button by lifting up the finger. The built button will only execute when the button is held down and another function is executed by lifting up on the finger.

The sample command using ASCII is shown as Fig. 5. When the user pressed the button forward, Arduino received command '1' from the Bluetooth signal. So, the event forward running. The command used in this built button are '1-4' where those represent forward, left, right and backward, respectively.

Movement of motor: For this study, the button command depends on the wheel direction. One wheel will move in

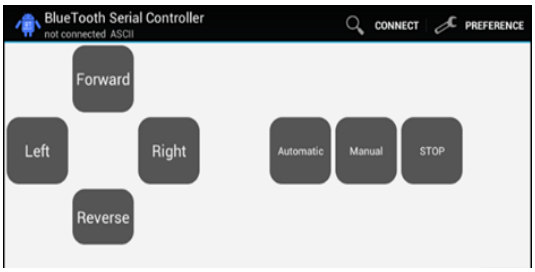

Fig. 4: Built controller button of vacuum cleaner robot

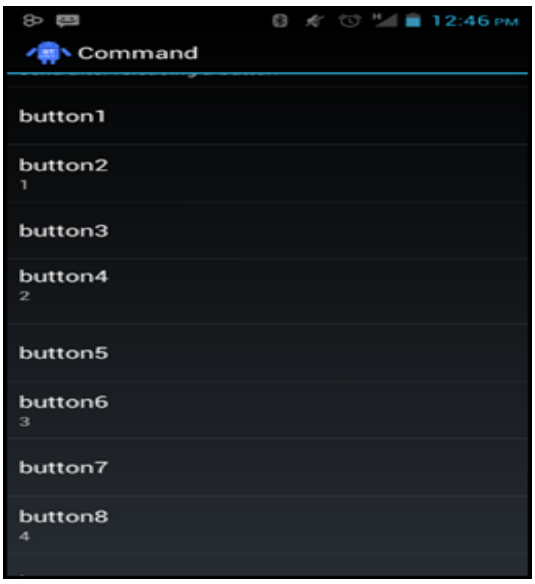

Fig. 5: Sample command for event button forward, left, right and backward

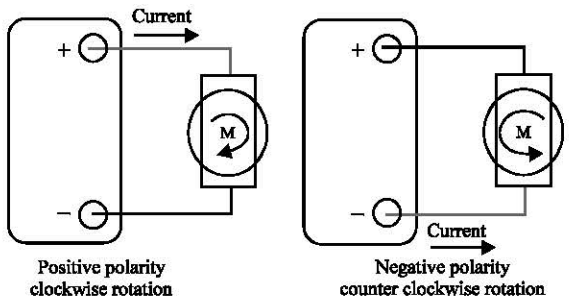

Fig. 6: Direction of DC gear motor for different current flow direction

reversed direction while another wheel moves in forward direction when turning to the right or left direction. This condition allows rotation of the vacuum cleaner robot at only one point. Figure 6 shows the direction of DC motor. The concept in the figure was used to change the direction of rotation of the DC gear motor. DC gear motor was controlled by motor driver L298N that received input data from the HC-06 Bluetooth module. The direction of the rotation of the DC motor is according to the configuration of the truth table from the motor driver L298N.

Table 1 shows the button configuration to make the movement of the robot vacuum cleaner. The truth table represents the functionality of L298N motor driver. Pin 4 until 7 are used as DC gear motor controller pin. Table 1 shows the truth table configuration for L298N motor driver.

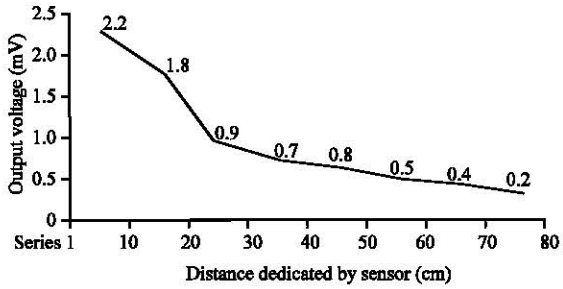

Fig. 7: Graph of output voltage with range between 10-80 cm

Table 1: The truth table of motor driver

Button command	Left wheel		Right wheel		Condition of robot vacuum cleaner
	PIN4	PIN5	PIN6	PIN7	
	(EN1)	(DIR1)	(EN2)	(DIR2)	
Forward	Duty cycle of PWM	0	Duty cycle of PWM	0	Move forward
Left	1	0	1	1	Move to the left
Right	1	1	1	1	Move to the right
Reserve	Duty cycle of PWM	1	Duty cycle of PWM	0	Move to backward
Stop	0	0	0	0	Stop

Analogue distanced sensor analysis: The analog distance sensor is used to detect an object or obstacle ahead. An analog distance sensor from SHARP2Y0A21F79 is used in this project. The analog voltage pin outputs and a voltage which corresponds to the distance. The closer an object is from the sensor the higher the output voltage becomes and the farther away an object is from the sensor the lower the output voltage becomes.

Figure 7 shows the behavior of voltage output with range between 10-80 cm where if the range between sensor and object is 10 cm, the output voltage will be 2.3 V. Meanwhile, if the range between the sensors is 80 cm, the output voltage will be 0.2 V. It is observed from the graph and trend line equation that the relationship between range and output voltage is linear.

In order to fulfill the requirement of a vacuum cleaner robot a sensor that can detect closer distance is required. In this project, distance of 10 cm is used to detect obstacle. If object <10 cm is detected the robot vacuum will turn left or else the robot will keep on moving forward. Thus, the range from 20-80 cm would not be used.

System test: As shown in Table 2 system suction test, the robot vacuum cleaner can only remove smallsize and light

weight materials. This result explain that the robot vacuum cleaner would not be functioning effectively for outdoor cleaning.

Table 2: Materials have been tested

Types	Results
Paper 	✓
Hair 	✓
Wooden acraps 	✓
Nails 	✘

In the experimental process, the obstacles are located at left, right and the middle region. As indicated in Fig. 8, the robot vacuum cleaner started the ground vacuuming within 20 min. If there is obstacle in front of the robot, the robot will turn left until there is no obstacle.

Figure 9 until 12 shows that the robot successfully moving according to the command given from Android smartphone. As soon as the manual mode is choose, the user can manually control the direction of the robot vacuum cleaner by Android smartphone. Since, the robot vacuum cleaner was not tested using external supply, so, the system testing on the movement is limitation.

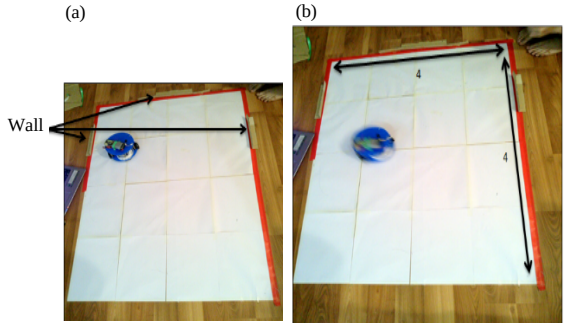

Fig. 8: The robot avoids obstacle in front of it

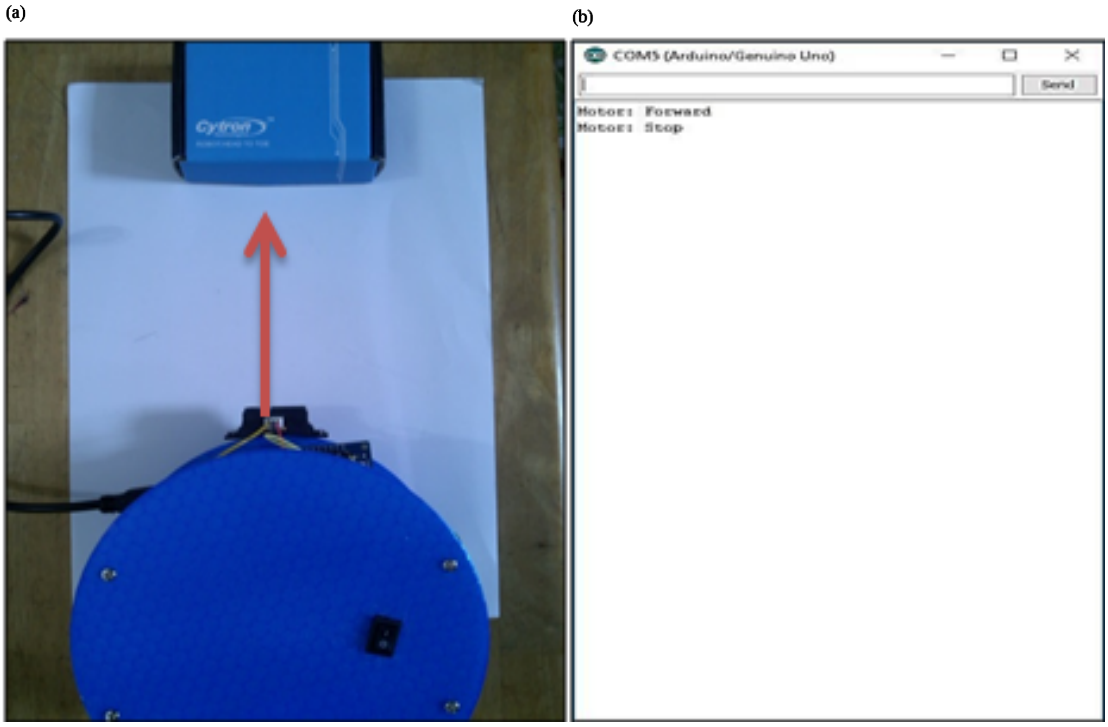

Fig. 9: a) Robot vacuum cleaner moving forward when button forward is pressed and b) Display output for forward event

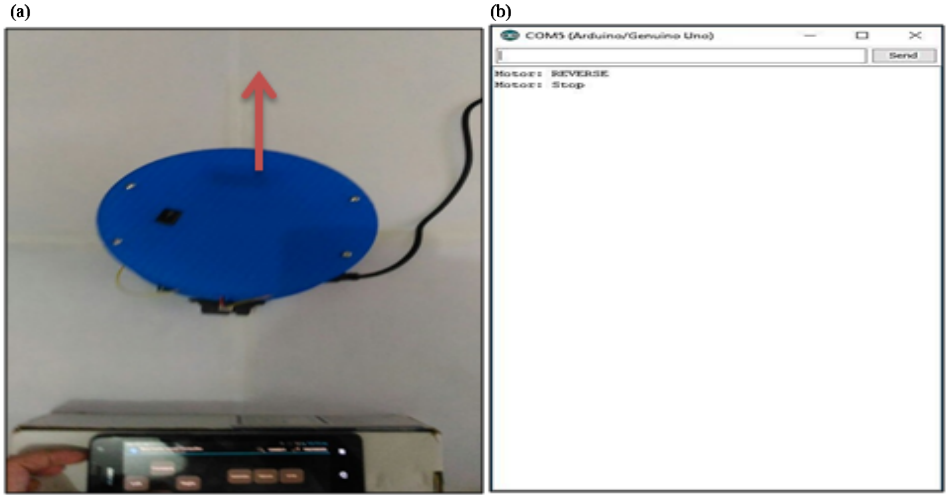

Fig. 10: a) Robot vacuum cleaner moving backward when button backward is pressed and b) Display output for backward event

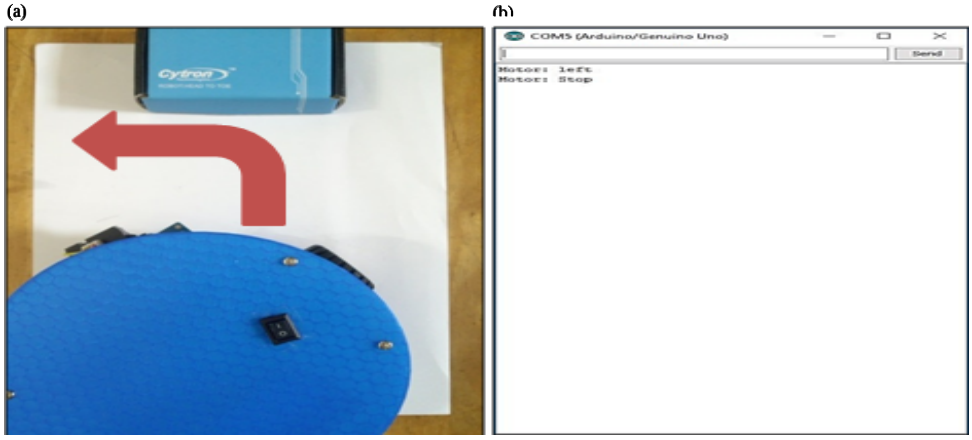

Fig. 11: a) Robot vacuum cleaner moving left when button left is pressed and b) Display output for left event

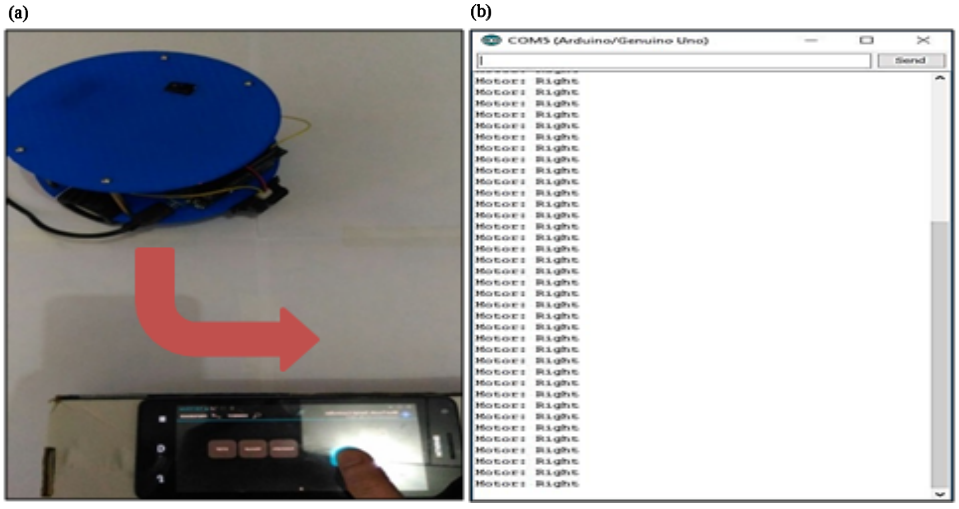

Fig. 12: a) Robot vacuum cleaner moving right when button right is pressed and b) Display output for right event

CONCLUSION

As conclusion, the objectives of this study have been achieved. Android system that can control the movement of a vacuum cleaner robot by using Bluetooth serial controller has been developed. The user can move manually the vacuum cleaner robot to the left, right, move forward and backward using the control interface. Besides, several research has been explored which is related with the project that is the development of vacuum cleaner robot. This project brings out some useful concepts which are the ability to provide convenience and better advantages to users. All the information in this project can be used for future research works and hopefully this can inspire our young generation engineers to design an excellent innovation that meets the market needs and public interest.

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