Design and Development of Automatic Cleaning and Mopping Robot

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Design and Development of Automatic Cleaning and Mopping Robot

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Abstract: In the present day scenario all the members of family are busy with their work and are not getting proper time to clean the house. The cleaning robot helps to clean and mop the floor. This is done by simply pressing a switch and the robot does the work. This also cuts down the labor used in factories for cleaning floor. Above being the case, motivated for the design and development of an automatic cleaning and mopping robot that does all the cleaning and mopping work with a simple press of a button. This robot can be controlled manually with the help of a mobile Bluetooth. The main moto of the project is to make this affordable and suitable for the Indian users and factories. The development of the robot starts with the design of a simple and most effective chassis for the robot which is a very important part as it has to carry all the weight on the robot. The electronics part where, the type of motor and its specification that should be used to run the bot, the sensors to be used, the microcontroller, the motor drivers, the wheels and other electronic components to be used on the robot are decided. Further, the assembling of the components will be done and finally testing and calibrating the device. A robot which is capable of efficient dust cleaning and moping of the floor of a given room is the main aim of the robot. It is aimed to make the robot economic and feasible for the economic class society. The target time of operation of the robot is one hour. The developed robot will be useful for the household application and industries. This helps to keep the workspace and house clean without the physical labor. Also, the device will clean the room with a single switch of button.

Keywords: Cleaning Robot, Mopping Robot, Automatic Robot.

1. Introduction

Robots are machines which are programmable and are able to carry out complex tasks with minimal human interventions. Robots find applications on many domains, even for household applications (5). Robots for domestic application have been rising. Vacuum cleaning robots are especially famous (8). Among various robots present in the world only some robots can be used especially for doing the household chores of man. Among those robots, one special kind of robot that is very useful for everyone is cleaning and mopping robot (12). A simple automatic robot that uses some prefixed algorithms and programs to clean the specified area is called a cleaning robot. The main use of this robot is to reduce the human interaction in the cleaning process which can be a time taking process (3). These robots can be used anywhere i.e., in offices, houses, industries etc. These robots can be activated with the press of a single button or can be pre-set to activate at a particular time (1).

There are many successful products in the market. The leading products are IRobot Roomba, Rrimin Smart Vacuum Cleaners Intelligent Automatic Sweeping Clean Robots, Exilient Ready Maid Robotic Vacuum Cleaner and many more (2). Every product has its own pros and cons. The main problem with these products is they are costly and not much compatible for Indian users (6). These products are much effective for wooden floor than the tiles. Some products do work for the tiles but this is available in

high-end versions only (10). Before the early discussions on the project, a market survey has been done in which a target group of 100 families was consulted and enquired about the cleaning and mopping robots (4). The result of this survey is as shown in the below figure.

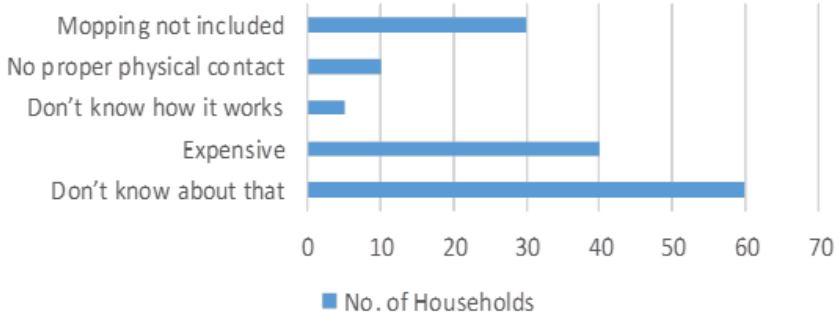

Figure 1. Market Survey on Automatic Cleaning Robot.

Figure 1, depicts the result of the market survey conducted on a target group of 100 families, from the figure it is understood that more than 60% of the families don't about the existence of such kind of robots and the 40% of them felt that the price of the robot is too high (9).
The main motto of the project is to make a vacuum cleaning and mopping robot which navigates based on information received from ultrasonic sensors and limit switches using an Arduino microcontroller, affordable and suitable for the Indian users and factories. Also, test the working of the robot replacing the IR sensors with the Ultrasonic Sensor, and including the mopping mechanism to the robot. Finally, make the robot effective on the ceramic tiles.

2. Design and Fabrication

Design of Automatic Cleaning and Mopping Robot starts with the design of simple and most effective chassis for the robot which is a very important part as it has to carry all the weight on the robot then electronics components which are to be used on the robot are decided which include the type of motor and its specification that are to be used to run the bot, the sensors to be used, the microcontroller, the motor drivers, the wheels and other electronic components to be used on the robot. After all, parts are procured assembling the components and finally testing and calibrating the device are done.

Figure 2. Design Methodology for the Project.

Figure 2, gives a brief idea of the how the design of Automatic Cleaning and Mopping Robot is done. It starts with deciding on the how the cleaning and mopping is done and ends with the testing and calibration.

Figure 3. Working Methodology of the Robot.

Figure 3, shows the working of Automatic Cleaning and Mopping Robot which starts by switching on the device, the robots move forward my checking for obstacles and avoids them if any. As soon as the robot is switched on it starts cleaning and mopping simultaneously and if any obstacle is there in its path it deviates from that and cleans the entire space.
The following figures show the designed and fabricated robot.

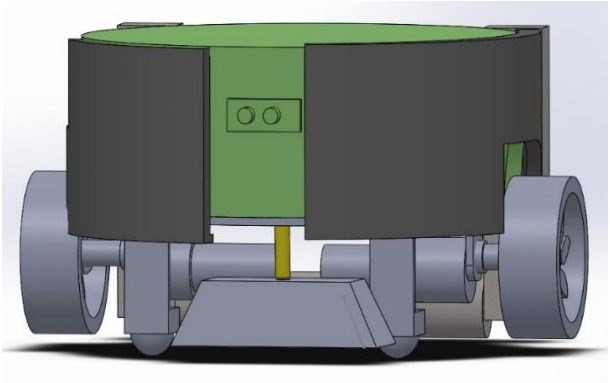

Figure 4. CAD Model of the Robot.

Figure 4, shows the CAD model of the robot designed in Solid Works software.

Figure 5. Vacuum Chamber of the Robot.

Figure 6. Vacuum Fan blades.

Figure 5 and 6, shows the vacuum chamber and the vacuum fan blades used in the robot respectively to clean the floor. This uses a high-speed motor for the suction.

Figure 7. Fabricated Model of the Robot.

The final fabricated model of the robot is as shown in the figure 7, it shows the front view of the robot.

3. Construction and Working

The robot starts by activating a simple switch. It simultaneously starts cleaning and mopping the floor. It follows per set path starting from one end of the room and finally completes the entire room cleaning. After reaching the other end of the room, robot changes its direction and follows the path perpendicular to the previous path. Robot changes the path if it encounters an obstacle. It can also be controlled by mobile phone using a Bluetooth. The path that the robot follows is a simple snake pattern as shown in Figure 8. In the figure, the blue lines depict the movement of the robot, the grey shaded region is the obstacle, and the brown part is the area that is not covered by the robot.

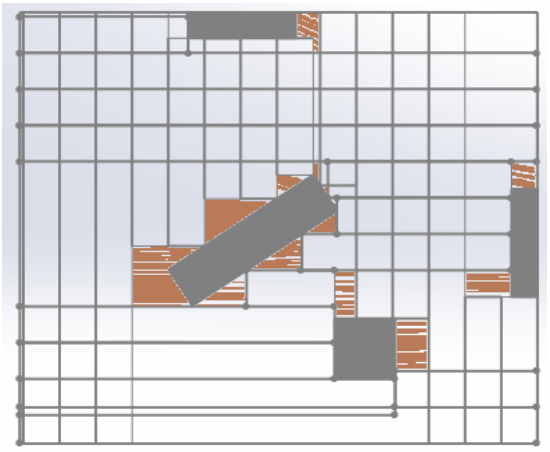

Figure 8. Pattern Followed by the Robot.

The movement technique used for the robot is a simple snake movement. The robot starts at a point A of the room as it reaches the side B of the room. It changes its direction and starts moving in the direction perpendicular to the previous movement. The robot starts to move forward as soon as it is switched on if there is any obstacle in its ways the ultra-sonic sensor the robot deviates. If the robot hit something it activates the limit switches behind the bumper and it deviates from the path. It the outermost switch is activated it deviates 30^0 from current path and if the robot hits an object and the inner switch activates then robot deviates 15^0 from the current path. If the robot hits an obstacle it comes back in the same direction and then it rotates into a new path, this made possible due to the use of L293D Motor Drive.

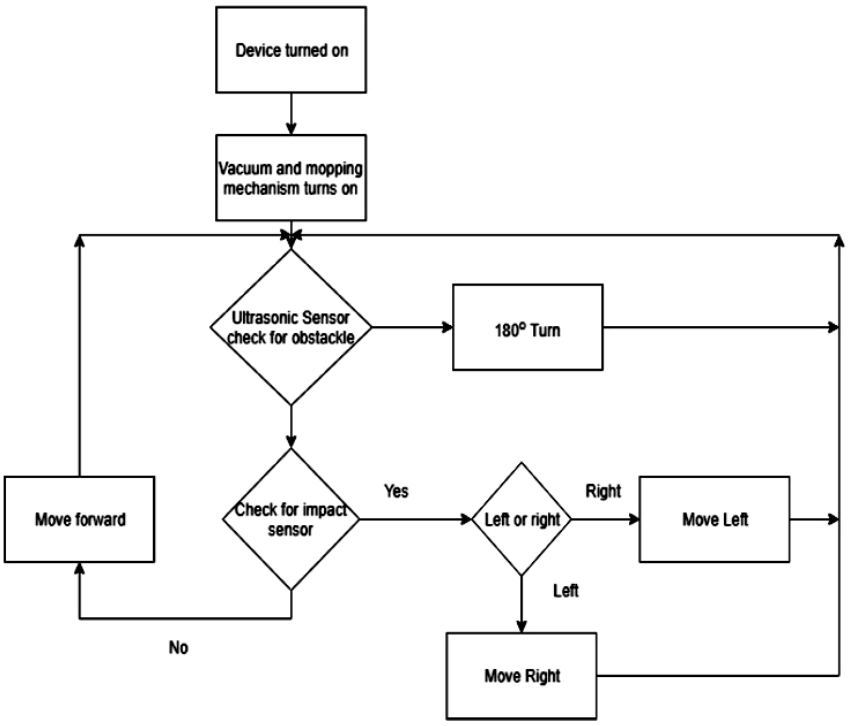

Figure 9. Flow Chart Showing Movement of the Robot.

Figure 9, illustrates a simplified flowchart of the working of the robot. When the bot is switched on the suction and mopping mechanism turns on, then ultrasonic sensor checks for the presence of any head-on obstacles. In case of any head-on obstacles it takes a clockwise or an anti-clockwise turn, in case of absence of obstacles, it checks for any impact on the bumpers. If any impact is detected, the robot moves away from the impacted object and in absence of impact it moves forward and checks for any head-on obstacles and the loop continues.

4. Calculations

The following are all the calculations that are done for the robot.

4.1 Calculations and Studies

Table 1. Design Details of Robot Body.

Design Consideration	Specifications
Diameter of the base	0.3 m
Thickness of the base	0.005 m
Height of the total body	0.22 m
Ground clearance	0.065
Thickness of the wall	0.002 m
Material used for base	Aluminium Composite Panel
Material used for wall	Fibre-Reinforced Plastic

Table 1, shows the design details of the robot which is made using the Aluminium Composite Panel (ACP) and the Fibre-Reinforced Plastic sheets (FRP).

4.2 Robotic Components Used

Table 2. List of Components Used.

Name of the Component	Number of Units
Wheel	2
Caster wheel	2
Battery	2
Arduino Uno	1
Motor Driving Module	2
DC Motor	2
Limit Switch	4
Ultrasonic Sensor	1

Table 2, enlists all the components that are used in the development of Automatic Cleaning and Mopping Robot which includes all the Sensors, Controllers and the Motors.

4.3 Calculating Time Required to Clean an Empty Room

4.3.1 Room dimensions

- Length of room (Assumption) = 4.8 m (L)
- Breadth of room (Assumption) = 4.5 m (B)

4.4 Calculating the Speed of Robot

- Number of drive motors = 2
- Radius of drive wheel (R) = 0.056 m
- RPM of each drive motor (N) = 60 RPM
- Width of the robot (W) = 0.33 m

- Speed (V) = R*ω
- ω = (2*π*N)/60
- ω = 6.28318 ≈ 6.28 radians/second
- V = 0.35 m/s
- Considering efficiency of power delivered to motor = 90%
- Speed delivered or Speed of Robot (Vr) = V*0.9 = 0.315 m/s
- Time taken by the robot to cover the room length once (t) = L / Vr = 4.8/0.315 = 15.238 seconds
- Number of passes required for robot to cover the entire room = Breadth of the room (B) / Width of the robot (W) = 4.5/0.33 = 13.63 passes ≈ 14 passes
- Total time taken by the robot to cover the entire room = 14*15.238 = 213.332 seconds ≈ 3.56 minutes ≈ 3 minutes 34 seconds (Max).

4.5 Calculating Distance that can be Cleaned with Fully Charged Batteries

Considering

- Maximum load condition on motors, current drawn by each motor = 1000 mA = 1A.
- Operating temperature = 25 °C.
- Discharge rate of the battery = Discharge rate of lead acid battery at 1-hour rate = 0.78 Ah.

As the motor draws 1A current according to our consideration, total time required for the battery to get completely discharged = 46.8 minutes.
Since lead acid battery shouldn't run past 80% of its charge, leaving 20% left in the battery in order to use it for multiple cycles, time taken by the battery to discharge 80% of initial charge = 46.8*0.8 = 37.44 minutes.
Since number of motors is equal to number of batteries which is equal to 2, considering each motor draws equal current of 1A from different batteries, total runtime of robot with fully charged batteries = 37 minutes 26 seconds = 2246 seconds.
Distance covered by robot = Velocity of robot (Vr) x Total runtime of robot = 0.315*2246 = 707.5 m.

5. Results and Discussions

The robot that was manufactured facilitates both mopping and vacuuming mechanism. It works in both manual and automatic modes. The entire project started after approximating weight of the robot. Based on the weight, the torque required for the robot to move was estimated and the market survey was done to get to the final motor which was high Torque Metal Geared DC motor had been used in the robot. The shape and size of the robot were decided to keep in mind the ease of navigation and programming. With the motor in hand the power supply to the robot is to be selected, keeping in mind the voltage supply and the current capacity the market availability was narrowed down and the Lead Acid Batteries were chosen to reduce the cost of the robot. The IR Sensors which were in use by most of the existing Cleaning robots were replaced by the Ultrasonic sensors which were more accurate. The bumper switches i.e., the limit switches were preferred over other non-contact sensors to increase the efficiency of the robot.
Many challenges had to be addressed during every stage of the development of the robot. These include Positioning of the Components, Wheel Alignment, Vacuum Chamber, Sensor Positioning, Motor Drive Overheating, and Navigation.
The robot was able to cover 90% to 92% of the area by following the patterns shown in the figures. The rest of the area can be cleaned using the Android mobile phone facilitated by the HC-05 Bluetooth module, this enables to clean the entire area. The Bluetooth controlled robot can be used to do the spot cleaning, which was not facilitated by the automatic cleaning method. The Bluetooth control also enables the ability to clean the difficult areas and assist the robot to do the repeated cleaning of the difficult areas.
In automatic mode, the robot took approximately 10 to 15 minutes to clean a room with the dimensions of 6m*5m. The robot runs for a total time of 35 minutes on full charge. It is able to simultaneously vacuum and wet mop the floor.

6. Conclusion and Future Scope

There are so many cleaning and mopping robots present in the market but only some of them are affordable and economic. There are very fewer robots that include both cleaning and mopping. With this work, we tried to reduce the cost of the robot and make it more compatible with the Indian Users and the Industries.

To further enhance the navigation performance of the robot, feedback sensors such as optical encoders can be integrated. Cleaner brushes can be added to vacuum cleaning mechanism to increase the efficiency of dust collecting. Lithium polymer batteries can be used to reduce the weight of the robot which can further lead to the reduction of power consumption.

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References

[1] Youngkak Ma, seungwoo Kim, Dongik Oh and Youngwan Cho, *"A study on the development of home mess- cleanup robot McBot"*, IEEE/ASME international conference on advanced mechatronics, July 2-5, 2008, Xian, China.

[2] B.N.Prashanth, V.Karthik, S.Karthikeyan, P.Raviteja, *"Design and Development of Drainage Inspection and Anti-clogging Robot",* Applied Mechanics and Materials, ISSN: 1662-7482, Vols. 813-814, pp 978-982, 2015, Trans Tech Publications, Switzerland.

[3] Xueshan Gao, Kejie Li, Yan Wang, Guangliang Men, Dawei Zhou and Koki Kikuchi *"A floor cleaner robot using Swedish wheels"*, IEEE international conference on robotics and biomimetics, December 15-18, 2007, Sanya, China.

[4] G Tuangzhi Dai and Tiequn Chen *"Design on measurement and control system of cleaning robot based on sensor array detection"*, IEEE International conference on control automation Guangzhou, May 30 to June 1, 2007, China.

[5] Veerajagadheswar Prabakaran, Mohan Rajesh Elara, Thejus Pathmakumar and Shunsuke Nansai *"hTetro: A Tetris inspired shape-shifting floor cleaning robot"*, IEEE International Conference on Robotics and Automation (ICRA), May 29 to June 3, 2017, Singapore.

[6] Yong-Joo Oh and Y. Watanabe *"Development of the small robot for home floor cleaning"*, Proceedings of the 41st SICE Annual Conference, 5-7 Aug, SICE 2002.

[7] H.G.T. Milinda and B.G.D.A. Madhusanka *"Mud and dirt separation method for floor cleaning robot"*, Moratuwa Engineering Research Conference (MERCon), 29-31 May 2017, Moratuwa, Sri Lanka.

[8] Yunbo Hong, Rongchuan Sun, Rui Lin, Shumei Yu and Lining Sun *"Mopping module design and experiments of a multifunction floor cleaning robot"*, Proceeding of the 11th World Congress on Intelligent Control and Automation, June 29 to July 4, 2014, Shenyang, China.

[9] J. Palacin, J.A. Salse, I. Valganon, and X. Clua *"Building a mobile robot for a floor cleaning operation in domestic environments"*, Proceedings of the 20th IEEE Instrumentation Technology Conference, May 20 to May 22, 2003, Vail, Colorado, USA.

[10] C. Hofner and G. Schmidt *"Path planning and guidance techniques for an autonomous mobile cleaning robot"*, Intelligent Robots and Systems '94. 'Advanced Robotic Systems and the Real World', IROS '94. Proceedings of the IEEE/RSJ/GI International Conference, Sept. 12 to Sept.16, 1994, Munich, Germany.

[11] M. Schofield *"'Neither master nor slave...' A practical case study in the development and employment of cleaning robots"*, Emerging Technologies and Factory Automation, 1999. Proceedings. ETFA '99. 1999 7th IEEE International Conference, Oct. 18 to Oct. 21, 1999, Barcelona, Spain.

[12] Zheng Zhao, Weihai Chen, Chen C.Y. Peter and Xingming Wu *"A novel navigation system for indoor cleaning robot"*, IEEE International Conference on Robotics and Biomimetics (ROBIO), Dec. 3 to Dec. 7, 2016, Qingdao, China.