Floor Cleaning Robot with 3D Printed Vacuum Impeller and Casing

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Abstract - *Cleaning the floors in houses and offices are now becoming painful for aged and weak people. Also air-borne infectants cause allergy to the people who are cleaning the floor. In order to reduce the difficulties faced while cleaning, a small floor cleaning robot model is proposed at an affordable cost. It is programmed to follow various paths and all the functions and path followed are controlled using an arduino board and obstacle sensors. Dry and wet vacuum are used for cleaning. Either only dry or both dry and wet can be used to clean the floor. To reduce the setup weight, vacuum motor capacity and battery capacity, the vacuum impeller and casing are 3D printed. Feasibility of the robot for domestic use and the efficient path is tested.*

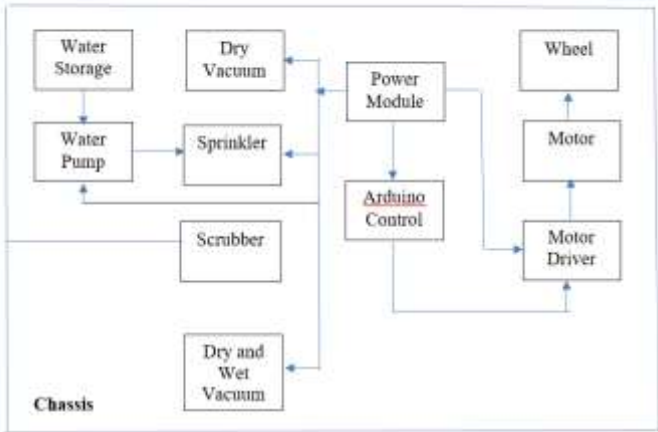
Key Words - 3D Printing, Arduino, BLDC Motor, Obstacle Sensors, Path.

1. INTRODUCTION

Cleaning the floor in houses and offices has now become tedious for aged and weak people. Since Robots were developed to help mankind in their work according to the requirement. So we have used it in domestic cleaning. The robot is developed to perform cleaning with various electronic and mechanical components with the help of programs and mechanisms. Therefore in order to help people in floor cleaning, this project is proposed. The available Cleaning robots like autonomous Vacuum Robot which cleans the floor similar to a Dry type Vacuum cleaner and autonomous Robot mop which cleans the floor with the help of water soaked mop are from leading manufacturers. Their prices start from around 40,000(INR).Other autonomous models like Mint perform both dry and wet cleaning and costs around 36,000(INR). Our proposed model performs both dry and wet cleaning and follows a programmed path based on obstacle detection. It costs around 8,000(INR).While manufacturing in large scale the cost would reduce further. The proposed Robot is less in weight when compared to manual vacuum cleaner. The important element that helped in reducing the weight is 3D printed vacuum setup. Two different impellers were 3D printed and three different paths are followed and tested.

2. SYSTEM CONFIGURATION

Table 1 : Block Diagram



3. METHODOLOGY

3.1. Model

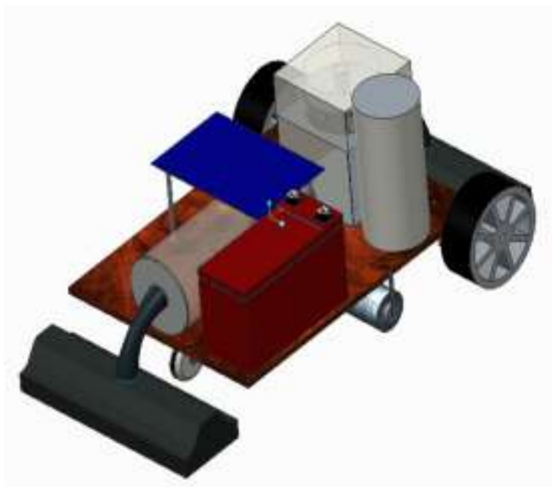


Fig-1: Model of the Robot

The robot was modelled in **CREO Parametric 2.0** Software

3.2. Challenges Faced

1) Cost Reduction

2) Optimization of weight

3) To optimize weight the impeller blades were 3D printed. It also reduces the vacuum motor capacity which in turn reduces the capacity and weight of the battery used. If the battery weight increases, the required capacity of the wheel motor increases which again increases the capacity of the battery. Hence 3D printing the impeller blades and casings will help in reducing the overall capacity and weight.

3.3. Components Used

Battery, BLDC motor, D.C motor, Impeller blade and casing, Wheel, Water Pump, Arduino Board, Ultrasonic Sensors, IR sensors, 3D Printing Filament, Plywood.

3.4. Component Selection

1) Wheel:

Weight of the plastic wheel = 250 g

Diameter – 10 cm

Width – 4 cm

Weight of Plastic wheel = 150 g

Material - Plastic and Rubber

Weight carrying capacity of a wheel – 2.5 kg

Weight carrying capacity of the castor wheel – 5 kg

Since two wheels and a castor is used, the total weight carrying capacity of the robot = 2.5 x 2 + 5= 10 kg

Total weight is shared among the three wheels.

2) Chassis:

Material - Ply Wood

Weight -750 g

Dimension - 35 cm X 25 cm X ½”

Water resistant plywood is used to avoid damage due to water spilling and to have high durability.

3) D.C.Motor:

Specification – 12V, 60 rpm,32 kgcm.

Shaft Diameter – 6 mm.

Type – Metal Geared.

Weight of the motor = 100 g

High torque motor is used in order to drive the overall weight.

Calculation

Approximate weight to be driven – 6kg.

Radius of the wheel – 5cm.

Torque required to drive the weight = Weight x Radius

=6kg x 5cm

=30 kgcm.

Hence D.C.Motor with 32 kgcm torque is used.

Since the required speed is low 60 rpm motor is chosen.

4) BLDC Motor:

Speed of the impeller required to create vacuum is high. Therefore, BLDC motor with 2200 kV specification is used. The representation implies that for a single volt given to the motor, the motor shaft rotates along with its casing at 2200 rpm.

Battery used - 12V.

Motor Specification – 2200kV

Maximum attainable speed = 12 x 2200= 26400 rpm.

Such high speed is important to create the required vacuum.

5) Motor Driver:

Motor draws more current and we cannot control it with a single transistor. So motor driver is used. A group of transistors called H bridge is the important element of the motor driver. L298 N Dual H Bridge motor driver is used which supplies 2A current.

Weight of motor driver = 15 g

6) Water Pump:

Weight of water pump = 50 g

Power Supply – 9V

Flow – 18 to 20 L/min

Since very less amount of water is required for sprinkling, low capacity water pump is used.

7) Battery:

A 9V battery is used to power the pump and a 12V 7Ah battery is used to power all other components use.

Weight of battery = 2Kg

Calculation

Current drawn by a BLDC Motor used = 1 A

Current drawn by a D.C. Motor used = 1 A

Total Current required = 2 x BLDC Motor Current +2 x D.C motor current

= 2 x 1 + 2 x 1

= 4 A

To drive the robot for 1 hour = 4 A x 1 hour =4 Ah

Therefore 4 Ah battery is required to drive the robot for 1 hour.

7 Ah battery is used, therefore the battery would power the robot for $\frac{7Ah}{4A}$

= 1.75 hours = 1 hour and 45 minutes.

8) 3D Printing Filament:

ABS (Acrylonitrile-Butadiene-Styrene) is used for its good strength and high melting point when compared with Poly Lactic acid (PLA)

9) Arduino Board:

The number of pins required is very less and hence UNO R3 was selected.

Weight of Arduino Board = 50 g.

10) Obstacle Sensors:

Ultrasonic sensors are used for Spiral and Square Wave paths whereas Both IR sensors and Ultrasonic sensors are used for Random path.

Weight of IR sensor = 10 g.

Weight of Obstacle sensor = 15 g.

3.5. Electronic Circuit

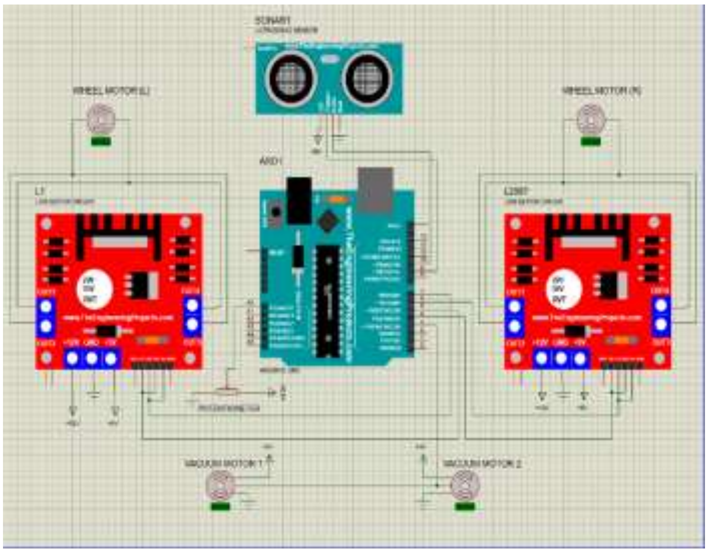


Fig-2: Electronic Circuit

The electronic circuit was designed in Proteus 8 software.

3.6. Path Planning

A wheeled robot can follow many path planning algorithms. We have tested with Spiral path , Random path and Square wave path.

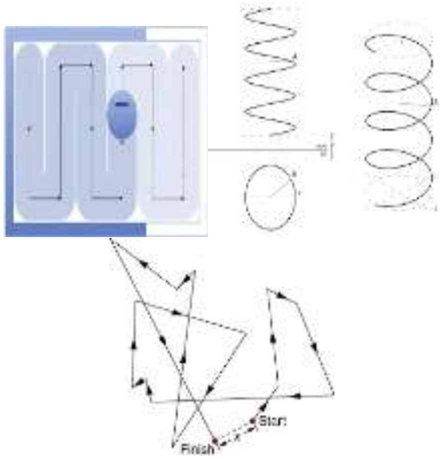


Fig-3: Square Wave Path, Spiral Path, Random Path.

3.7. Vacuum Setup

1)Vacuum Model

The Vacuum setups were modelled using SOLIDWORKS 2016.

Fig-4: Volute Casing

Fig-5: Bottom Casing

Fig-6: Impeller 1

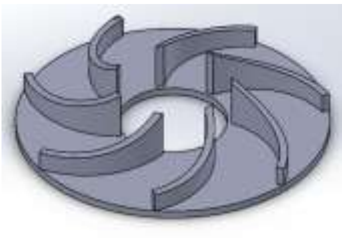


Fig-7: Impeller 2

Two different impellers were modelled and 3D printed. Efficient among the two is selected and installed in the vacuum pump.

2) 3D Printed Vacuum Model

The vacuum setups were 3D printed using a custom made 3D printer similar to Prusa i3 with a single extruder. The material used for printing was Acrylonitrile Butadiene Styrene (ABS).The setup was modelled using SOLIDWORKS 2016.

The models were saved as .STL (Stereolithography) file. The saved file was sliced using a slicing software called REPETIER HOST. The printer was connected to the slicing software and then printed. Extruder of the printer was maintained at 250°C and the bed is maintained at 60°C

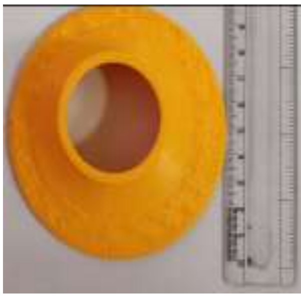


Fig-8: 3D Printed Volute Casing **Fig-9:** 3D Printed Bottom Casing

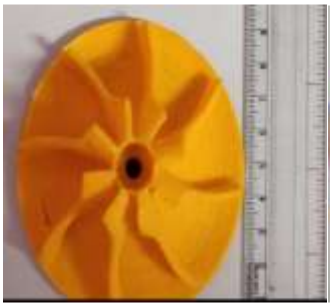


Fig-10:3D Printed Impeller 1 **Fig-11:**3D Printed Impeller 2

3.8. Fabricated Setup

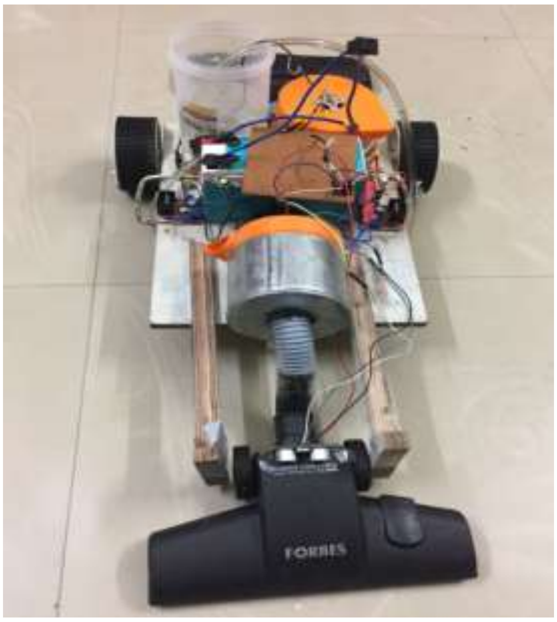


Fig-12: Fabricated Setup

4. RESULTS AND DISCUSSION

For a 10 ft X 10 ft room (100Sq.Ft) only with room boundaries, our floor cleaning robot took following time to cover the whole area for different paths followed.

Table 2: Experimentation and Output

PATH FOLLOWED	TIME TAKEN
Spiral Path	3 min 53 s
Square Wave Path	3 min 12 s
Random Path	Not Applicable*

*Calculation of cleaning time for random path is not applicable because, when compared with other two paths it would take very long time to cover the area and there is no certainity in cleaning the whole area. The efficiency of Spiral path is higher compared to the other two paths in terms of cleaning.

The efficiency of impeller 1 is higher than impeller 2 in terms of creating vacuum and hence Impeller 1 is used in our robot to create vacuum.

- Vacuum created by impeller 1: 202.5 mm of Hg column or (0.2699 bar)
- Vacuum created by Impeller 2: 327.8 mm of Hg column or (0.4371 bar)

From the observations mentioned above, impeller 1 and spiral path is chosen for better efficiency in terms of cleaning and time.

5. CONCLUSIONS

Thus a floor cleaning robot that cleans the floor with less or no human intervention was fabricated and has the following advantages.

- Reduces the exposure to air-borne infectants.
- Reduces muscular fatigue.
- Less human work required.
- Low cost.

In case of overcoming household obstacles, a very minimal or negligible area may be left uncovered. In order to overcome this, SLAM (Simultaneous Localization and Mapping) can be used. Mapping of path can be done to clean the whole area with precision.

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