DESIGN AND DEVELOPMENT OF AUTOMATIC FLOOR CLEANING ROBOT USING MEGA 328P

P. S. Barve[1]*, S.V. Prayagi[2], N. P. Mungle[3], V. S. Vairagade[4], M.D. Muley[5]

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Abstract-
With the advancement of technology, researchers are focusing more on automated floor cleaning machines to make human life more comfortable. The concept is gaining traction in developed countries, but it remains unpopular due to design complexity, machine costs, and operational charges in terms of power tariff. The goal of the design and development of an automatic floor cleaning robot using a mega 328p and a Bluetooth module is to create a floor cleaning robot that is both cost-effective and useful in everyday life applications. This robot will be designed to help with the heavy cleaning required when there are food stains on the floor. This robot will be an all-in-one Mop-Clean-Dry combination. To control the robot, it will employ wireless technology as well as Smartphones. The overall goal of this project is to design and build a floor cleaning robot that is both useful in daily life and cost-effective enough that people can afford such machines.

Keywords: Robot, food stains, smartphone, Bluetooth, etc

[1*,2,3] Department of Mechanical Engineering, Yashwantrao Chavan College of Engineering, Nagpur, India,
[1]Email: purubarve5@gmail.com, [1]Orcid id: 0000-0002-0835-1433,
[2]Email: sunil_prayagi@yahoo.com, [3]Email: npdmungle@gmail.com,
[4] Department of Civil Engineering, Priyadarshini College of Engineering, Nagpur, India,
[4]Email: vikrantvairagade@gmail.com,
[5] Department of Mathematics, S B Jain Institute of Engineering, Technology and Management, Nagpur, India
[5] Email: manjushreemuley@sbjit.edu.in

***Corresponding Author:** P. S. Barve
*Department of Mechanical Engineering, Yashwantrao Chavan College of Engineering, Nagpur, India, 441110. Email: purubarve5@gmail.com, Orcid id: 0000-0002-0835-1433

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1. Introduction

When Residential Floor Cleaning Robots are considered, they are either very expensive to be afforded by any family. In the end, it is not only about affordability but the usefulness of the available robots is also low. Most of them are made using Vacuum which means that they are just mobile Vacuum cleaners that can be controlled without touching them. The cost of these robots is very high starting from around INR 10000/- which is very high for a Vacuum cleaner. The problem is not only this but these robots do not solve the problems of cleaning the floor. The real challenge of floor cleaning is that when there are liquid spills. The stains may not be easily removed using traditional and the robots are using Vacuum which places them nowhere to solve the problem.

2. Research background

As for the reference, the previous works related to this project were thoroughly analysed. There were many works related to Floor Cleaning Robot. Each one has some pros and some cons. But they have one thing in common, they all worked using vacuum technology. Till now, almost all the Floor Cleaning Robots were using vacuum technology to clean the floor. They can clean all the dust and dry litter present on the floor. Some of them use either prebuilt Arduino Board to control the robots whereas others use one of the microcontrollers to control it. All of them use a battery as the main source of energy but the type of battery varies as per the works. They can be either Li-ion batteries or Lead-Acid batteries. Many of them do not have wireless access using either Wi-Fi or Bluetooth. But the thing most of them lack is that they cannot clean wet floors or liquid stains. As for the household floor, there can be any type of dirt on the floor like wet or dry. But these robots only clean the dry part leaving the wet or stains as it is.

3.Research methods

3.1 Overview

Work Done section of the thesis consists of all the components, technology, methodology, design parameters, calculations, working, and costing of the project. Following will be the overall work done on the project and all the technical details.

3.2 Previous Designs

The previous works related to this project have a similar design concept. All the models had 4 wheels to keep it moving. In some of the models, there were brushes mounted on the front side of the robot to scrub the dirt on the floor and the inlet of vacuum was present on the backside. Heavy equipment like batteries, were placed in the front side to keep CG in the front to maintain stability. The dirtbags for the vacuum cleaner were placed on top of the robot at the backside.

3.3 Preliminary Design

Following is the preliminary design of the Robot after discussions and considering various design constraints. This design is done using CAD Software named SOLIDWORKS. This design is various views are as follows: -

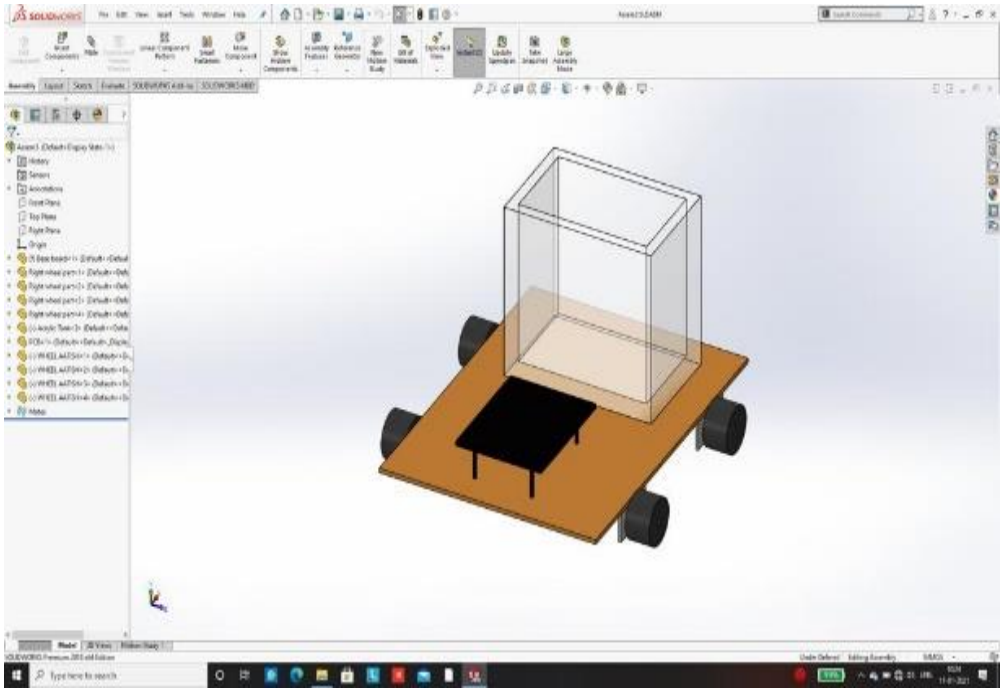

Fig 3.1: - Initial Design of Robot in CAD

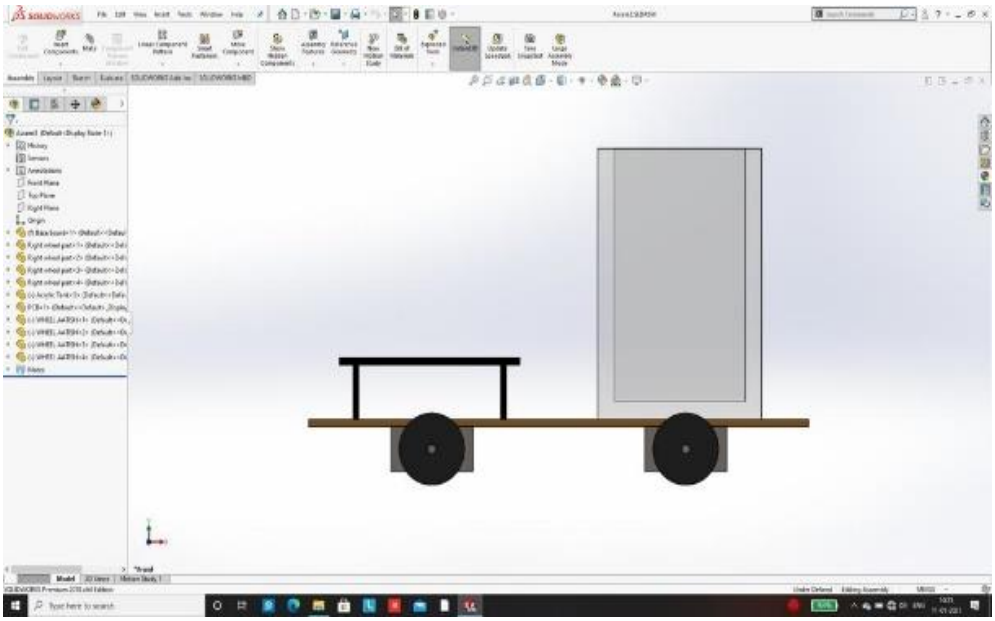

Fig 3.2: - Side view of Initial Design

3.4 Components

In any design and fabrication project, there are various components that are required for the designing and fabrication part. This section will explain which electronic components will be used, their technical specification and why it is being used against other counterparts available in the market of that component.

The components to be used in the project are as follows: -

1. Atmega328p: Atmega328p is a micro controller. By the term, microcontroller means that it has a Processor, RAM, and ROM in-built at the same time as against a Microprocessor in which RAM and ROM must be installed externally. This helps in minimizing the circuit complexity. By reducing circuit complexity, more focus can be given to the programming part than designing the circuit to integrate RAM and ROM.

2. L293D Motor Driver Module: Motor Drivers are the IC or Integrated Circuits which are used to control a DC motor according to the signals from Microcontroller. The reason for using a Motor Driver to run a motor rather than connecting the motor directly to the Microcontroller is that the output voltage of the Microcontroller is not enough to run for most of the motors since the Microcontroller output is around 5.5V and the voltage required to run the motor must be 12V. So, to run the motor to its full potential, the supply must be 12V. Therefore, an additional circuit must be used which can take the signal from Microcontroller and deliver the signal to the motors at 12V. Hence, the circuit used in-between is called Motor Driver.

3. 12V 12Ah Li-ion Battery: There are various types of batteries available in the market. But, the one to suit this project is the Li-ion Battery. Li-ion batteries are compact, lightweight, have high power capacity and stability over a long range of temperature differences. This gives an upper hand while designing this project as this battery has less weight and has high power. Therefore, 12V Li-ion Battery is the most optimal choice for this project as the maximum requirement is 12V and less weight.

4. L7805CV Linear Voltage Regulator: In order to achieve the said conditions, L7805CV Linear Voltage Regulator must be used as it is low cost and delivers an average output voltage of 5V with a minimum threshold voltage of 7V which means that a minimum 7V must be supplied in order to run the regulator.

5. 12V DC Motors: A mobile robotic device cannot be designed without the use of motors. In this project also there is a need for motors for various applications like mobility and giving power to mops. Motors are electromechanical devices that convert electrical energy to mechanical energy. These machines or devices are used where power input is in electrical form and mechanical movement is required.

6. HC-05 bluetooth module: HC-05 bluetooth module: HC-05 module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with

complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04-External single-chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has a footprint as small as 12.7mmx27mm. It is very easy to integrate with Atmega328p. Using this robot and Smartphones can be connected and can be controlled using a mobile application.

7. RELAYS: Relays are used as a switch in a given circuit. Relays have two inputs and one output. One input is directly from the power supply and the other is from the Microcontroller. Microcontroller signal acts as a switching signal means that upon receiving the high value from the controller, the relay enables the channel which led the power from the other input flow and is supplied to the motor. Therefore, relays are best suited for the motors used for moping.

8. PUMP: In this project, a 24V Diaphragm Pump will be used whose discharge rate is around 1-2 cc/sec. As the operating voltage is 24V, an additional amplifier must be used to boost the voltage from 12V to 24V.

9. HIGH-SPEED FAN: There are various fans available in the market that can be used in this project. But, Stone-Pro 12V DC Fan is one of the best available fans that can work on 12V supply as they are CPU fans and are Brushless. Brushless means that the supply to the motor of the fan does not contain brushes which reduces contact losses due to the contact of the brush and the winding. It works best with a 12V supply and can be easily integrated with Atmega328p. It also has proper mounting as it is also used for processors in Computers. This mounting can be directly used to mount the fan on the chassis and directly can be used.

10. FLOAT (SWITCH) SENSOR: For this project, a side-mounted Float Switch will be used as these sensors are limited to the length of its float rod. But if side-mounted are used, then they can be mounted from in between the tank which will be considered to be the minimum water level point.

3.5 Working

Now, as the calculations are all done, the functions of the robot can be explained.

Following is the block diagram of the working of the robot: -

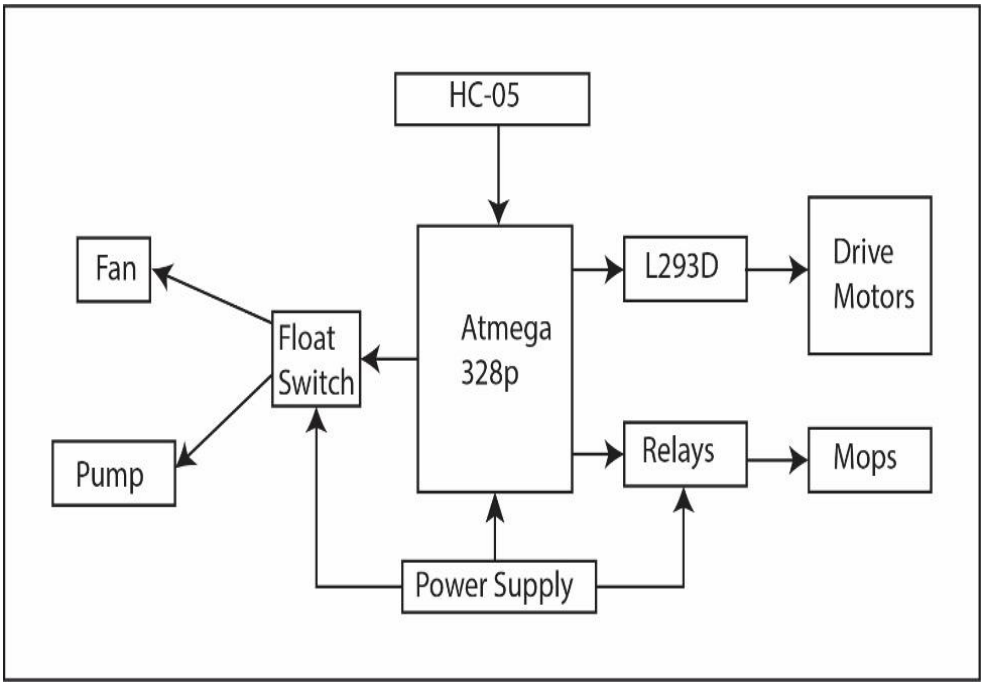

Fig 3.3: - Block Diagram of Robot

In order to start the working of the robot, it must be first connected to the Smartphone via a Bluetooth connection and an android app which will be used to run the operations of the robot. The User Interface of the App is as follows along with the labeling of the buttons for which it will be used: -

The actual working procedure of the robot is as follows: -

1. Initially the power to the robot is turned on.
2. After there is power in the robotic system, the Bluetooth connection must be made with the Smartphone having the android app.

3. In order to check if the connection is successful, the red LED light on the HC-05 Bluetooth module will stop glowing once the connection is made. This ensures that there is a successful connection between the devices.
4. Once the connection is successful, the water level must be ensured. If the water level is low then the power should be off and the water tank must be fully filled with water and then steps I to III must be repeated.
5. Once this is completed, then click the Mop On/off button to start the mop. Here, as soon as the button is pressed, the app sends a signal to the robot to start the mop. The signal is processed and a necessary function is triggered to start the mop. Once the function is triggered, the controller sends a signal to the necessary relay switch which will get activated and the mop starts spinning.
6. After this, the Pump button must be pressed. On pressing this button, this signal goes to the controller commanding it to start the pump and the fan. But before these two components start, the controller triggers a check function on the float sensor to check if there is the proper amount of water available in the tank. If there is the proper amount of water available in the tank then the float sensor signal will be used to verify and after verification, the start pump and fan function will be triggered which will send a signal to the necessary relay to start these two components.
7. After that, the user can move the robot in any direction using the direction keys. Whichever key the user presses, the signal travels instantly to the robot, and the controller processes the signal and transmits a required signal to the Motor driver module which will control the movement of the robot.

All the above steps can be repeated in order to perform the necessary cleaning operation on the house floor.

3.6 Mathematical Calculation: -

For any type of calculation in a design, the first step to be taken is an assumption. Assumptions are made according to the requirements of the design of any product. Requirements are decided according to the functions that must be included in the final product. Therefore, this project also needs some assumptions. They are as follows: -

1. The dimension of 12in x 9in for the bot area and material is acrylic are considered for initial calculations.
2. Water capacity for the robot is considered 2 liters. Therefore, the weight of the water is considered 2kg.
3. The use of Li-ion battery in place of Lead-acid battery as they are lightweight and cover less area.
4. As per the components considered, the weight of the 12V 12Ah Li-ion battery is around 500gm according to the datasheets.
5. There is no bending in the board.
6. Components are placed in symmetry.

The calculations for various aspects of the robot are as follows: -

1. Considering a room of 10ft x 10ft which is needed to be cleaned in 5min of time: -

The number of passes needed to clean the room of considered dimensions = 13

The number of turns taken for 13 passes = 12

2. For the geared motor of 12V 60RPM as per the required components: -

The total distance to be traveled by the robot to clean the floor

= passes x length

=13x10ft

= 39.624m

Time taken to turn the robot is estimated to be 3 sec.

5min = 300 sec

Total time is taken by the robot to turn = 36 sec

Time of travel = 300 – 36 = 274sec

Speed required = 39.624/274= 14.46 cm /sec

w (angular velocity) at 60 rpm = 6.28 rad/sec

v = rw

r = 2.3 cm is the minimum radius required to clean the floor in a given time.

As the minimum radius required to achieve the target timing is 2.3 cm, the selection of wheel radius is considered 3cm, and the material for a tire is considered rubber as it is most effective on the floors of almost all houses.

For the wheel of diameter 6cm, time is taken to clean the floor = 4min 7 sec

3. Now, the robot needs to start moving. In order to do so, it needs some torque to be produced on the motor so that it starts moving from its static position. There are various calculations that are to be done which are as follows: -

Total weight of the robot = Total Force (F) = 24.5 N

Coefficient of rolling resistance (Crr) = 0.011 (average Crr for rubber with asphalt and rubber with cement)

Rolling Resistance RR = F x Crr =0.2695N

Initial velocity (Vi) = 0

Final velocity (Vf) = 0.1446m/sec

Time (T) = 0.1 sec
Vf = Vi + at, therefore, a = 1.466 m/sec^2
Grade resistance (GR) = 0 as floor will be flat always
Acceleration force (FA) = ma = 3.615N
Tractive force (Tr) = RR + GR + FA = 3.8845N
Torque required T = Tr x d/2 = 0.1165 Nm
Therefore, the torque required to just move the robot from its static position comes out to be 0.1165Nm.

4. After torque, the minimum power needed for the robot to run is to be determined: -

Power required for one motor P = (2 x pi x N x T)/60 = 0.732 W
Power required to run 4 motors = P x 4 = 2.928 W
Energy required = Power p * time of operation in hour
= 2.928 x 247 / 3600
= 0.2 Whr
0.2 Whr is the minimum amount of energy required to run the robot using only 4 motors of mobility and keeping all other components like mops and fan off so that it can clean the room of a given area.

5. The above is the minimum energy requirements which are always less than that of actual. The above calculations are done for ideal conditions means that the efficiency is 100%. But in a practical scenario, efficiency is always less than ideal. Actual calculations are as follows: -

All the components have their own range of power consumptions starting from no load to full load. But for calculations, full load consumption rate must be considered.
According to datasheet, the motor to be used draws 200-300 mA of full load current. Therefore,
Actual Power Consumption of Motor
= 12v * 0.3A (highest possible current)
= 4 W * 4
= 16 W for 4 motors
Actual energy consumption = 16 * 247/3600
= 1.09 Whr
1.09 Whr is the calculated energy consumption based on the current drawn by the motor at full load and time required to clean a room of 10ft x 10ft in a set time of 247 seconds.

6. Till now all the calculations were of 4 motors that will be used for the traveling of the robot. But other components consume power too. So, there is a need to consider the power consumption of those components also.

Power consumed by Atmega 328p = 22mW = 0.022 W (according to data sheet)
Power to run Mops =>
Assuming no load on mops. Therefore, 60mA of no-load power consumption of motors of the mop. 2 mops totals 120mA of the current draw at 12v.
Total power consumption for mops = 1.44 W
Power consumption of drying fan = 2W (according to datasheet)
Therefore, total power consumption by all the components except 4 running motors is = 0.022 + 1.44 + 2 = 3.462W
Also, total power consumption by all modules = 16 + 3.462 = 19.462W

7. After finding the total power consumption of all the components, let's move on towards the battery. The battery is the power storage of the robot. All batteries have rated voltage and capacity they have been designed for. But rated quantities are just like ideal cases in the case of a battery. That means the actual capabilities of the battery are different than rated. There are conditions in which battery ratings are affected during working conditions.

The rated battery capacity = 12V * 12Ah = 144Whr
On average, the actual capacity of the battery is around 80% to that of rate.
Therefore, actual capacity = 0.8 * 144 = 115.2Whr

8. As for the total working efficiency of robots, theoretical efficiency is considered to be 80% of any standard working efficiency of any electronic device. Therefore, the actual power consumption comes out to be: -

Actual power consumption = Total Power / efficiency = 19.462/0.8
= 24.3275W

9. As the actual capacity of the battery and actual power consumption is calculated, the total continuous working of the robot from fully charged to full discharge of the battery can be determined. The total continuous working time comes out to be: -Duration = Actual battery capacity/ Actual power consumption

= 115.2 / 24.3275
= 4.73 hours

3. Result and discussion

- The area to be cleaned was considered to be 5ft x 5ft for the experiment against the assumed calculations. After performing the cleaning process using the robot over a number of times, the following are the observations: -It was observed that the time taken by the robot to turn for the next pass was 5 seconds against the assumed value of 3 seconds.

- The total time taken by the robot to clean the 5ft x 5ft area for a total of 7 passes was 106 seconds i.e., 1min 46 sec.
- Removing the time taken by the robot to turn 6 times for 7 passes comes out to be 76 seconds. That means that to cover a distance of 35ft which is 10.668m the robot took 76 seconds. That means that the robot travels at a speed of 14cm/second against previously calculated 14.42 cm/second.
- Now using this speed, it is easy to calculate the time taken for a 10ft x 10ft area. That means that in order to cover the distance of 39.624m, the robot will take 283 seconds. And considering the 5 second turn time for 12 turns is 60 seconds the total time for the whole cleaning process of the given area comes out to be 343 seconds.
- 343 seconds are the actual time needed to clean the floor of 10ft x 10ft.

4. Conclusion

The Floor Cleaning Robot which is designed, developed, and fabricated turns out to be very efficient, cost-effective, compact, and easy to use. The amount of water storage present is sufficient. The cost of the robot is far less than that of other similar robotic devices available in the market. The wireless connection of the mobile app and the robot is very efficient and there is visually no lag in communication with the robot. The use of this robot is also very fun as it feels like playing with a remote-control car.

As a result, the project is successful in all terms. But the robot is still not perfect and needs a lot of further research and development if this concept is to be rolled out into the market. Further development of this robot is beyond the scope of this project. But this is a good step towards the future of robotics.

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