Autonomous Floor Cleaning Robot with Obstacle Avoidance Technology

Ajay Gaikwad[1], Mayur Bhanushali[2*], Pranay Dhongade[3], Soumitra Athalye[4], Medha Asurlekar[5]
[1,2,3,4]*Student, Department of Electronics Engineering, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India*
[5]*Assistant Professor, Department of Electronics Engineering, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India*
*Corresponding author: mayur.bhanushali@somaiya.edu

***Abstract*: The paper discusses an Automated Robotic Vacuum Cleaner with reliable and cost effective navigation system. The core idea behind the project is to minimize the cost. Nowadays, due to fast and hectic lifestyle, it is difficult to spare time for cleaning purposes. This problem is solved by our robot. The robot follows various algorithms for area mapping and optimized cleaning. These algorithms try to reduce cleaning period and eliminate human intervention as much as possible.**

***Keywords*: AFCR, LIDAR, UDM, IR sensors, Spiral motion, Random walk, Snaking, Wall-following algorithms.**

1. Introduction

A. Origin

Dust is a common air pollutant generated by many different sources and activities. Dust is common in urban areas. It is created by a range of activities from personal hobbies, such as gardening, to large scale industrial and construction activities. If the area is not regularly cleaned, then rubbish and dirt will build up. Germs and parasites will multiply and grow in the dirt and people living in the house may get sick. There are many ways to clean dust which require human intervention. The time spent by a person to clean the dust can be saved to do some productive work. Hence it becomes necessary to come up with innovative ideas to clean up dust and debris.

B. Need

Keeping your home beautifully clean every day is hard but important work. Dust dirt and hair build-up everywhere which can be cleaned by taking the aid of a traditional vacuum cleaner. Vacuum cleaners are bulky, cumbersome machines that are often hard to move around the home [1]. Moreover, in the case of an upright vacuum cleaner it is almost impossible to move up and downstairs. The vacuum cleaner was manufactured in a fairly large size, although not heavy. Moving and storing this device will require a big place. Depending on the vacuum cleaner model uses hundreds to thousands of watts of electricity. Absolutely, if you use a vacuum cleaner, your electricity bill starts running. Cleaning with a vacuum cleaner also requires human intervention. These lead to the loss of time which could have been utilized more productively.

C. Objectives

- The objective of the research is to design and develop low cost Automated Robotic Vacuum cleaner.
- Automatic Vacuum Cleaner should be able to do an effective navigation system with the help of optical sensors.
- It should clean the given room effectively. The cleaning should be done by efficient algorithms.

2. Related Work

The First cleaning machine that used a vacuum and that could be carried around was designed by Walter Griffiths in 1905. It used bellows to suck up dust and a flexible pipe. James B. Kirby invented vacuum the machine in 1906, called the “Domestic Cyclone”, which used water for dirt separation instead of a filter. Traditional Vacuum Cleaner was heavy and operated by humans. It was heavy in weight and large in size and the size of a dirt-bag was also large. Remarkable changes made in vacuum cleaners were a low size and low power consumption, but the cost of these vacuum cleaners was much higher. After that, with the help of Navigating systems (such as LIDAR and SLAM) cleaning bots get advanced features which include modes of cleaning, mapping of the room. LIDAR (Light Detection and Ranging) is a remote sensing method that uses light in the form of a pulsed laser to measure distances and map the surrounding objects. These light pulses, combined with other data recorded by the airborne system generates precise, three- dimensional information about the shape of the surrounding objects and its surface characteristics. A LIDAR instrument principally consists of a laser, a scanner, and a specialized GPS receiver. Two types of LIDAR are topographic and bathymetric. Topographic LIDAR typically uses a near- infrared laser to map the land, while bathymetric LIDAR uses water-penetrating green light to also measure seafloor and riverbed elevations [2]. Simultaneous localization and mapping (SLAM) is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. Current vacuum cleaners use these technologies for scanning and creating maps of the room [1].

3. Interdisciplinary Relevance

The Automatic vacuum cleaner is created by implementing the concepts of various fields such as Embedded, Pneumatic, Electric and Mechanical systems. They are discussed below:

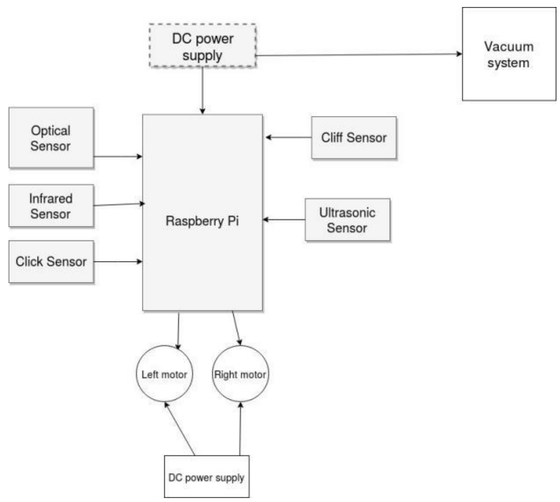

Fig. 1. Block diagram of AFCR

A. Embedded System

Raspberry Pi 3 Model B+ is the brain of the complete system. This single-board computer is interfaced with sensors (Infrared, Ultrasonic and Optical sensors) and actuators (DC Motor, Vacuum System) which together perform the complete operation of cleaning. The computer also generates a map on the basis of the data collected from the optical sensor which plays a key role in the navigation system.

B. Vacuum System (Pneumatic System)

It works on the principle of the flow of air from areas of high pressure to areas of low pressure. An electric motor is attached to a fan that spins it at high velocities. The fast-spinning fan creates a region of low pressure inside the suction hose of the vacuum cleaner. Air, along with dust and debris is sucked into the suction hose because of the pressure difference between the outside and inside of the suction hose [3].

C. Electrical and Mechanical System

The power subsystem is an integral part of the electrical system. Rechargeable Lithium-ion batteries are used to power up all the other components of the system. Most of the power is consumed by the vacuum system because it requires a high-speed motor to create a pressure gradient. A set of DC motors are used to drive the vacuum cleaner and to implement sweeping brushes [4].

4. Description of the Robot's Components

- Cliff sensors: Sense the stairs or the drop-offs, this keeps it from tumbling down the stairs.
- Object sensors: when AFCR bumps into something then it helps to find a new path around the object and continue its job.
- Infrared and Ultrasonic distance meter: it sends out a signal and checks how long it takes for a signal to return. This tells AFCR the size of room and also helps navigating.
- Click sensors: Detects the wall.
- Components Raspberry Pi 3 Model B RAM - 1GB LPDDR2 Processor- Cortex A53 64bit Soc, 1.4GHz
- Sweeping Brushes 3 Arms each at 120° Rolling Brushes Dimensions- 19 x 5.5 x 3.5 cm
- Motors Rated Voltage- 12V, Torque- 4.0kg-cm/4000RPM
- Ultrasonic Sensors Maximum Range 400cm Infrared Sensors Range up to 20 cm
- Optical Sensor USB Connectivity, 1000 DPI sensitivity Li-ion Battery 12V, 100Ah rating.

Table 1
Components of AFCR

Components	Description
Raspberry Pi 3 Model	B RAM - 1GB LPDDR2 Processor- Cortex A53 64bit Soc, 1.4GHz
Sweeping Brushes 3	Arms each at 120°
Rolling Brushes	19 x 5.5 x 3.5 cm
Motors	Voltage-12V, Torque-4.0kg-cm/4000RPM
Infrared Sensors	Range up to 20 cm
Ultrasonic Sensors	Maximum Range 400cm
Optical Sensor	USB Connectivity, 1000 DPI sensitivity
Li-ion Battery	11.1V, 4200mAh rating

5. Navigation Algorithm

Navigation algorithm of the robot is basically dependent on the sensors and micro-controller and algorithm fed to it. The sensors first collect the data from the environment and feed it to micro-controller. The micro-controller processes this sensor data and the robot moves accordingly. Navigation can be defined as the combination of the three fundamental competencies:

- Self-localization
  - Active approach
  - Passive approach
- Path planning
  - Spiral Motion Algorithm
  - Random Walk Based Algorithm
  - Snaking and Wall Following Algorithm

A. Self-localization

Robot localization denotes the robot's ability to establish its own position and orientation within the frame of reference. Path planning is effectively an extension of localisation, in that it requires the determination of the robot's current position and a position of a goal location, both within the same frame of reference or coordinates [5]. Map building can be in the shape of a metric map or any notation describing locations in the robot frame of reference. Hence to establish our self-localization system, we came up with two approaches namely, active and passive approach. The active approach utilizes an optical sensor for localization. The optical sensor feeds the robot with coordinates so as the robot can track and localize in the environment. Whereas in the passive approach, the AFCR uses its velocity, directionality and timing properties to calculate the coordinates. Since this approach doesn't use any sensors, we termed it as the passive approach.

1) Active approach: As stated, the active approach is based on an optical sensor. When the robot is initially turned on, it declares its initial position or the base position as as $x_b(0, 0)$. The optical sensor gets initialized and it starts to provide relative coordinates in terms of the robots current position. On any movement, the optical sensor sends the relative coordinates x_r on the basis of the velocity and the direction. These relative coordinates are either added or subtracted from the base coordinates to get the current coordinates, i.e. $x_c = x_b \pm x_r$. In this way, the robot can keep track of its current position with respect to its environment. The addition or subtraction depends on the direction in which the robot moves. If the robot takes a complete 180° turn, the relative coordinates provided by the sensor are subtracted from the base coordinates. These specific operations are described in the algorithm of the Active approach.

2) Passive approach: In this approach, the robot self-determines the relative coordinates which were provided by the optical sensor in the active approach. To calculate the relative coordinates, the robot utilizes the information like RPM of the motors causing motion, velocity and directionality of the robot. For every unit distance the robot moves, it makes corresponding changes in the base coordinates (either x or y coordinate according to direction). For turns, the robot switches the coordinates (if current coordinate was x then changes it to y and vice-versa) accordingly. In this way, the AFCR tries to maintain a localization system. But it may be possible that due to some physical parameters and non-ideal situations, the approach may turn unreliable. Hence we restrict the use of this approach for wall-following algorithms, where the robot traces the map of the room.

B. Path planning

1) Spiral Motion Algorithm: If the robot has sufficient space on its 4 sides it will move in a spiral path at first half of its running. The spiral path can be anti-clockwise and clockwise. The spiral path can be generated by the decreasing ratio of left motor encoder and right motor encoder [6].

2) Random walk based algorithm: Basically random straight path searches from one node to another by the help of natural heuristic search. After the spiral motion the robot if detects a collision then it follows the edge of the wall until it gets enough free space for spiral motion again. After some moment if it does not get any specific clear area for spiral motion then it will move in a random path for some time and the obstacle detection and avoidance system will be carried out by the help of ultrasonic sensors [6], [7].

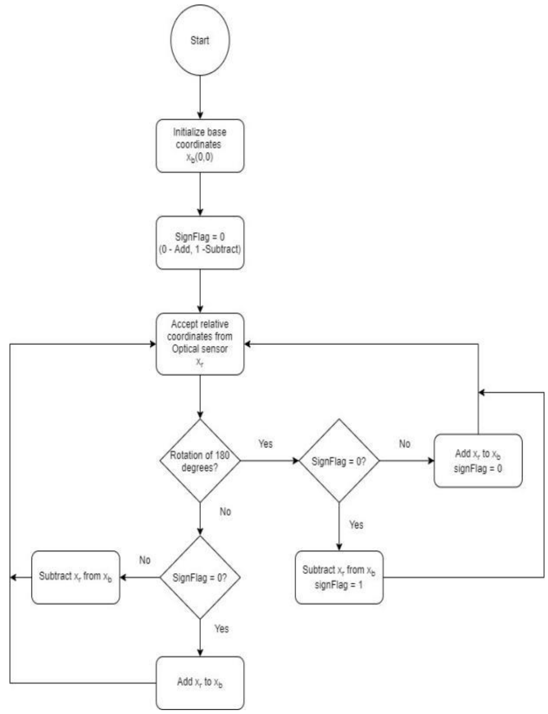

Fig. 2. Flowchart for self-localization with active approach

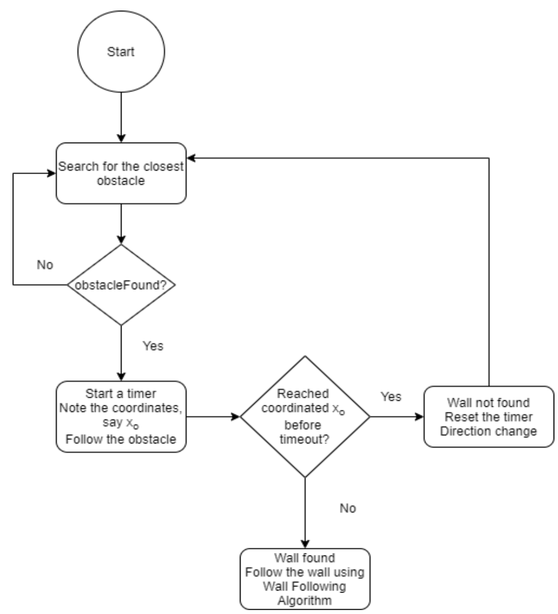

Fig. 3. Flowchart for wall following

3) Snaking and Wall follow algorithms: Path planning based on a snake-like movement is also common for domestic robots. This pattern realistically generates many errors as it potentially must perform lots of stopping and rotating. Consider that wheels are not aligned or that sensors are cheap and imprecise. Over time errors will accumulate. For this reason, the authors suggest using the snaking pattern only for local, small areas that are cleared quickly in order to prevent positional errors accumulating. combine the snaking path with a random walk path so that the random walk explores the room and the snaking pattern is used for the actual area coverage. Wall follow paths are mainly used to allow the robot to gain knowledge of a room's perimeter. the robot moves forwards until it collides with an obstacle. Thereafter it performs turns until the robot is no longer colliding and can continue along the edge of the obstacle. Wall following is particularly useful for clearing tricky spots such as corners [7].

6. Expected Results

Automatic Vacuum Cleaner will be able to scan and map the room efficiently. According to the map generated, it will detect obstacles, its position (Coordinates of the object), It should follow the preloaded algorithm for the first time (i.e. at the time of Mapping). After mapping the room, the controller will create a map of the given room as accurate as possible. Then it will move in the room by the most efficient algorithm which will be decided by the controller. Automatic Vacuum Cleaner will clean corners of a room which are often difficult to clean which is done by 'D' Shaped on front side. The efficiency of Vacuum cleaner will be high. It will clean garbage like small dust particles, paper pieces, sand, soil, etc. Efficiency can be increased by increasing number of rounds around the room.

7. Conclusion

Keeping your home beautifully clean every day is hard but dust, dirt and hair build-up everywhere, so for cleaning floors of your home at the push of a button we designed the Autonomous Floor Cleaning Robot. It is designed to clean the room efficiently. AFCR is also helpful for elder people to clean their home to avoid from back pain. Its advanced navigation system seamlessly navigates working non-stop until your home is beautifully clean. A full suite of sensors and an optical mouse system help the AFCR map your home. It is designed for real homes and large-scale industries inspired by various vacuum cleaners present in the market. The construction cost of this Vacuum cleaner is nearly half of the vacuum cleaners present in market.

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