Smart Suction Cleanser

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***Abstract*—The purpose of this paper is to design and implement a Robotic Vacuum Cleaner. It is designed to automate the tedious process of cleaning. Various aspects such as physical dimensions, sensor placement, robot navigation, safety are considered for the optimal implementation of this robot.**

Keywords—Domestic robot;Embedded systems;Automation; IR sensors; Vacuum Cleaner.

I. INTRODUCTION

The consumer demands are approaching automated systems that can save their time & also relieve from many tedious and repetitive tasks. Cleaning is usually a tedious, boring, and repetitive task and thus a clear candidate for the application for robotics [1]. This motivated us to design a mobile robot which could relieve from the tedious task of cleaning. There are several research papers dealing with the navigation of mobile robots. However, there are very limited papers dealing specifically with floor cleaning robots.

Hence, In this paper we have mainly concentrated over the dimension constraints, the sensor placement, navigation and the overall design of the robot. 'Smart Suction Cleanser' is an intelligent device which is programmed to detect and avoid the obstacles with the help of IR sensors mounted on it body. It is capable of accomplishing its tasks because of it's unique code fed inside the microcontroller.

II. ROBOT DESIGN LAYOUT

Fig. 1 shows the proposed 2-Dimensional design of 'Smart suction cleanser'.
The mechanical design of a cleaning machine for domestic use must be ergonomic and small enough to move around the typical obstacles in a household room and as well as light enough for easy transportation in case of unexpected problems [1]. Hence all the parameters are considered while designing the physical structure of the robot.
While designing, Several different problems need to be resolved, like, the efficiency of the cleaning device, the placement of the motorized wheels, the on-board sensors, and the battery recharge operation.

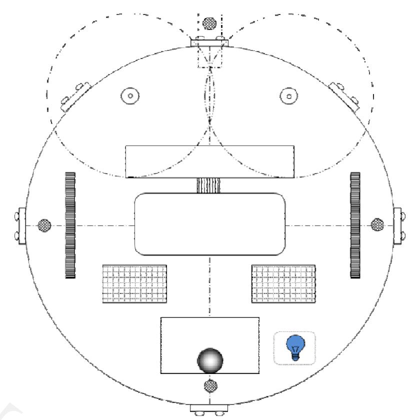

Fig. 1. Design layout of 'Smart Suction Cleanser'.

A. *Dimensional Constraints*

In our design, the main emphasis is given on portability and mobility of our robot, But making the robot as compact as possible is a challenge. Vertical dimensional constraint is of more importance as it should perform cleaning operations where human encroachment is limited. For example, Under beds, furniture etc.

Considering the domestic usability of this project the universal ground clearance for furniture is to be considered and it was more than 5 inches. As this is a proposed design we managed to keep the height of the robot between 4 to 4.5 (inches). Smart Suction Cleanser consists of a circular body of diameter 14(inches.)

B. *Overall description of 'Smart Suction Cleanser'*

The Smart Suction cleanser uses 4 motors, i.e., 2 for navigating in the environment & 2 for rotating the rotary brushes. The DC motors are supplied with a 12V DC source provided through the Motor Driver L293D which also controls the direction of rotation of the motors. Overall 10 Sensors are used for detection of obstacles in the environment, six around the periphery of the robot and 4 (marked as solid circles) in Fig. 1.on bottom side of the robot.

The high power vacuum especially designed for 'Smart Suction Cleanser' is placed an inch behind the intersection of two rotary brushes. A caster wheel is used to balance the robot also enabling the robot of having a Rotation of 360 (degree). It has a rechargeable battery which can give 40 minutes of continuous operation. A dust box is disposed at the side of a battery where the dust is collected.

III. CLEANING MECHANISM

The cleaning mechanism incorporated in 'Smart Suction Cleanser' is specifically designed to effectively collect the dust and store it into dust-box. The Suction principle can be easily explained with the help of following figure.

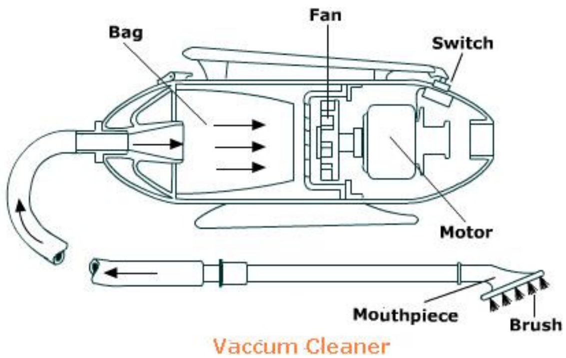

Fig. 2. Vacuum Principle

A. Vacuum Principle

The electric current operates the motor. The motor is attached to the fan, which has angled blades. As the fan blades turn, they force air forward, toward the exhaust port. When air particles are driven forward, the density of particles (and therefore the air pressure) increases in front of the fan and decreases behind the fan [3].

This pressure drop behind the fan is just like the pressure drop in the straw when you sip from your drink. The pressure level in the area behind the fan drops below the pressure level outside the vacuum cleaner (the ambient air pressure). This creates suction, a partial vacuum, inside the vacuum cleaner. The ambient air pushes itself into the vacuum cleaner through the intake port because the air pressure inside the vacuum cleaner is lower than the pressure outside [3].

B. Vacuum Implementation in 'Smart Suction Cleanser'

As seen in Fig. 1. The cleaning mechanism has two rotary brushes one of which rotates in clockwise direction and the other in anti-clockwise direction. The two rotary brushes guide the dust particles to the vacuum inlet where the dust particles are sucked in by the vacuum suction.

High power suction is created by rotating a high r.p.m fan with a dc motor.

The fan driven by the dc motor reduces the pressure near the mouthpiece. The pressure due to atmosphere being large, forces air along with dust particles into the dust box [2].

IV. SENSOR SELECTION AND PLACEMENT

Sensors play a key role in the operation of the Smart Suction Cleanser. For this the sensors must be placed in appropriate position to accomplish the desired tasks. The tasks include detection of obstacles in the environment and to navigate the robotic device through a suitable path.

A. Sensor Selection

Very often obstacles avoidance tasks rely on ultrasonic sensors where the measuring data of the sensors are first used to gain a local representation of the environment in order to afterwards control the robot accordingly [4].

But IR sensors are simple, commonly employed, and relatively low-cost sensing modalities to perform the wall-following task. Sometimes, IR sensors may be preferable to ultrasonic sensors due to their faster response time, narrower beam width, and lower cost. Unfortunately, the intensity of the light detected depends on several parameters including the surface reflectance properties, the distance to the surface, and the relative orientation of the emitter, the detector, and the surface. Due to single intensity readings not providing sufficiently accurate information about an object's position and properties, the recognition capabilities of simple IR sensors have been under used in many applications [4].
Although these devices are inexpensive, practical, and widely available, their use has been mostly limited to detection the presence or absence of objects in the environment (proximity detection) for applications such as obstacle avoidance, counting or wall-following [4].

After this literature survey we came to a conclusion of using IR sensors as it was simple to implement and yield satisfactory results for obstacle detection and wall-following.

B. Sensor Placement

In this Robot, ten infrared sensors are utilized for distance measurements. The infrared sensor consists of a LED emitting the infrared light and a photo diode. This sensor enables to detect objects without any influence on the color of reflective objects, reflectivity, the lights of surroundings. Maximum range that can be detected is from 10 to 30 cm. It generates an analog voltage that is a function of range. The output voltage can be measured by an analog-to-digital ADC input line. It has three wires, positive (+5V), negative (ground), and data output.

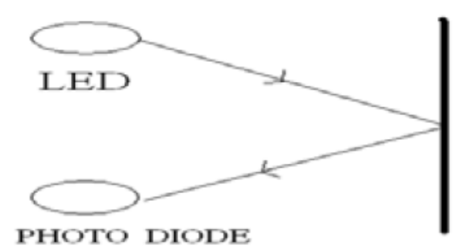

Fig. 3. Working principle of IR Sensors

There are 6 IR proximity sensors to sense the distance from obstacles around the device and adjust its course of movement accordingly.

Their placement is shown in the designed layout. Refer Fig. 1.

Also 4 Cliff sensors are placed front, left, right & back on the bottom of the device to prevent it from tumbling down stairs or falling form a height which may damage the appliance.

V. FUNCTIONAL BLOCK DIAGRAM

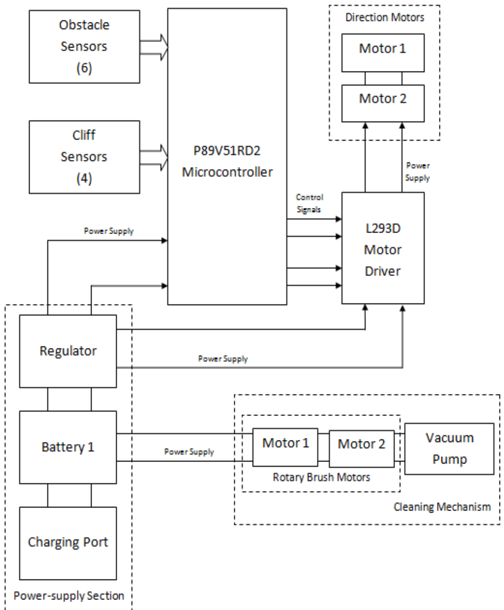

Fig. 4. Block Diagram of 'Smart Suction Cleanser'

The Entire Project can be summarized by referring the Block Diagram.

A. Block Diagram Description

1) **Microcontroller: -** Microcontroller is used to control the movements and trajectories of the Smart Suction Cleanser on the field. Here we use μC P89V51RD2 with 64 KB of Flash RAM to store the required Program & also to generate various control signals to navigate the Smart Suction Cleanser in its environment for the cleaning operation.

2) **Motor Driver: -** Motor driver used here is L293D which can efficiently drive two motors at a time. The motor received power from a 12V DC source and relays the current through the motors in accordance with the control signals received from the Microcontroller P89V51RD2.

3) **DC Motors: -** Smart Suction cleanser uses 4 motors, i.e., 2 for navigating in the environment & 2 for rotating the swiping brushes. The DC motors are supplied with a 12V DC source provided through the Motor Driver L293D which also controls the direction of rotation of the motors.

4) **Sensors: -**The sensors used by Smart Suction Cleanser are all IR sensors which are designed to accomplish two tasks, viz. detecting the obstacles in the environment and to detect the cliffs coming in the path.The transmitter is an IR LED & the receiver is TSOP1738 which together make a sensor pair.

5) **Power supply: -** The complete assembly of Smart Suction Cleanser is supplied with 12V DC supply. For Microcontroller & Sensors the voltage is stepped down to 5V DC.

VI. DEVICE NAVIGATION

Navigation of Smart Suction Cleanser is dependent on the data received from the IR sensors. The data from the sensors is fed to the micro-controller which commands the robot accordingly to change its trajectories. The microcontroller is programmed with a smart algorithm which includes all permutations and combinations of all possible obstacles that the robotic cleaner can encounter while its operation in the work environment.

VII. TECHNICAL SPECIFICATIONS

TABLE I. 1

Sr. No	Parameter	Specification
1.	Vacuum Device	i) Body Shape : Circular ii) Diameter : 14" iii) Height : 3.9" iv) Weight 4 Kg
2.	Sensors	i) Obstacle Detection = 6 ii) Cliff Detection = 4 Total = 10
3.	Software Language	Embedded C
4.	Power-supply	12VDC 1.2mA Li-ion Battery
5.	Charging Port	Available
6.	Vacuum Capacity	0.5 L
7.	Operating Time (Hr.)	30-40 minutes
8.	Degree Of Rotation	360^0

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