A Technological Survey on Autonomous Home Cleaning Robots

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Abstract- In this present era, people live a very busy life. People in cities have irregular and long working times. In such a situation a person will always find ways of saving time. household chores are the ones that are most dreaded upon. And cleaning a home tops the list.

It is not only time consuming, but also its very tiring. Especially for working women it becomes difficult to handle both home and office work together. She has to do the household chores in the morning, go to work and do the works there and return home in the evening to again start her chores at home. Thus she lives a dual life. In this dual life, we thought of gifting her away of saving some of her precious time.

The requirement of a House Cleaning Robot is born. For saving time we needed an automatic system that cleans on its own without human interventions. Also, we did think about how to aid people with physical disabilities. Since we had to do this, we knew that we needed a cleaning system that could work in accordance to what we say, thus helping a physically disabled person.

Index Terms- house cleaning robot, automatic system

I. Introduction

The house cleaning robot uses a microcontroller to detect obstacles and manipulates its direction as per the inputs from infrared sensors mounted in front, right and left of the robot or the digital signal processor.

The heart of the system is a microcontroller. It is programmed to accept inputs to sense obstacles around it and control the robot to avoid any collisions. There are 4 IR sensors used in this project- one at the front, and the remaining on the left, right and back of the robot to detect obstacles, if any. In case of an obstacle, or a potential collision, the microcontroller controls the wheels of the robot by a motor driver to avoid collision. The vacuum cleaner mounted on the robot performs the cleaning process[1].

Auto mode: In this mode, the microcontroller is programmed in such a way that it takes the decision and changes the path of the robot as per the sensor inputs to avoid the obstacles. A timer is used to set the time limit for the cleaning process.

II. System Block Diagram

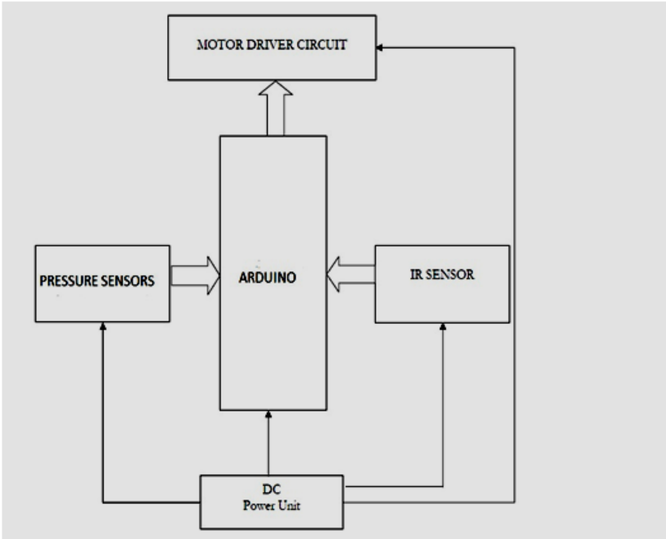

Figure 1: Block diagram of proposed design[1]

A. *Block Diagram Explanation*

1) DC power unit

This block consists of a 12 V rechargeable battery and a voltage regulator. The LM7805 IC connected to the output of the battery, provides a constant output of 5V[2] regardless of the load in the circuit. Thus the power requirements of the system are strictly met without putting the system at risk during high loads.

2) Microcontroller

The microcontroller is the heart, which makes the system automatic. The microcontroller reads the signals from the IR sensors and the digital signal processor. It then processes this data and controls the movement of robot by giving signals to the motor driver.

3) IR sensors

An astable multivibrator, an IR LED and an IR sensor TSOP1738 constitutes the IR sensor block. Here we use four pairs of IR LED and sensor for the automatic operation of the House Cleaning Robot. The multivibrator is set to produce square wave oscillations at a frequency of 38 kHz[2]. The output of the multivibrator drives the IR LEDs. When an obstacle comes in front of the robot, the IR rays gets reflected from the obstacle and falls on the IR sensor, which turns the normally high output of sensor to off. It controls the movement of robot according to the output of the IR sensors.

4) Motor driver circuit

A motor driver is used to control the two geared DC motors. It can make a motor rotate in either clockwise direction or in anti-clockwise direction according to the control inputs given to it. The microcontroller provides the control signals to the motor driver IC according to the output of DSP in manual mode or IR sensors in automatic mode.

III. FLOWCHART

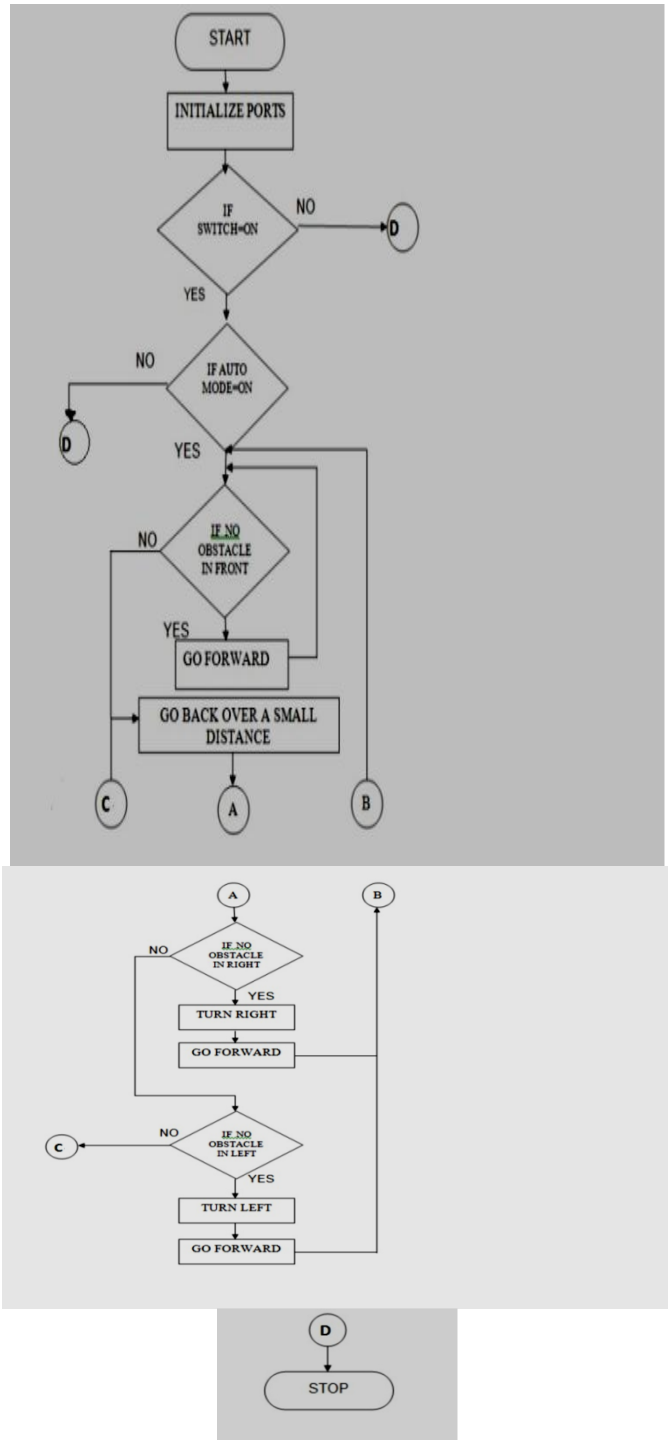

Figure 2: Flowchart defining steps of the dataflow

IV. TECHNOLOGICAL PRODUCT SURVEY

A. DESCRIPTION

All Roomba models are disc-shaped, 34 cm (13") in diameter and less than 9 cm (3.5") high. A large contact-sensing mechanical bumper is mounted on the front half of the unit, with an omnidirectional infrared sensor at its top front center. A recessed carrying handle is fitted on the top of most units.

As of 2012, there have been four generations of Roomba units: the first-generation original models, the second-generation "Discovery" series, the third-generation 500 series and the fourth-generation 600/700 series. All utilize a pair of brushes, rotating in opposite directions, to pick up debris from the floor. In most models, the brushes are then followed by a squeegee vacuum, which directs the airflow through a narrow slit to increase its velocity in order to collect fine dust. A horizontally mounted "side spinner" brush on the right side of the unit sweeps against walls to reach debris not accessible by the main brushes and vacuum. In the first generation of robots, the dirty air passes through the fan before reaching the filter, while later models use a fan-bypass vacuum.

The Roomba is powered by removable nickel-metal hydride batteries (NiMH), which must be recharged regularly from a wall power adapter. Newer second and third generation models have a self-charging homebase which they automatically try to find at the end of cleaning session via infrared beacons. Charging on the homebase takes about three hours. Four infrared "cliff sensors" on the bottom of the Roomba prevent it from falling off ledges such as the top steps of stairways. Most second- and third-generation models have internal acoustic-based dirt sensors (The Dirt Detect Series 1 Technology) that allow them to detect particularly dirty spots (zones having excess particulates) and focus on those areas accordingly. Fourth generation models have an optical sensor located in front of the vacuum bin (The Dirt Detect Series 2 Technology) allowing Roomba to detect wider and smaller messes. Many second and third generation Roombas come packaged with IR (infrared) remote controls, allowing a human operator to "drive" the robot to areas to be specially cleaned.

B. OPERATION

All Roomba models can be operated by manually carrying them to the room to be cleaned and pressing the appropriate button. Later models introduced several new operating modes. "Clean" mode is the normal cleaning program, starting in a spiral and then following a wall, until the room is determined to be clean. "Spot" mode cleans a small area, using an outward-then-inward spiral. "Max" runs the standard cleaning algorithm until the battery is depleted. "Dock" mode, introduced with the third generation, instructs the robot to seek a self-charging homebase for recharging. The availability of the modes varies depending on model, generally with higher-end units having more features.

The robot's bumper prevents them from bumping into walls and furniture by reversing or changing path accordingly. The third- and fourth-generations, which move faster than previous models, have additional forward-looking infrared sensors in its bumper to detect obstacles. These slow down when nearing obstacles to reduce its force of impact (Light Touch Technology). Additionally, this technology is able to distinguish between soft and solid barriers. After a sufficient period of time cleaning, the Roomba will either search for and dock with the homebase, or stop where it is.

The cleaning time depends on room size and, for newer models equipped with acoustic dirt sensors, volume of dirt. First-generation models must be told the room size, while second- and third-generation models estimate room size by measuring the longest straight-line run they can perform without bumping into an object. When finished cleaning, or when the battery is nearly depleted, a second- or third-generation Roomba will try to return to a homebase if one is detected. A second-generation Roomba may also be used with the external Scheduler accessory, allowing cleaning to start automatically at the time of day and on days of the week that the owner desires. Most 500 Series robots support scheduling through buttons on the unit itself, and higher-end models allow the use of a RF remote to program schedules.

Unlike the Electrolux Trilobite vacuuming robots, Roombas do not map out the rooms they are cleaning. Instead, iRobot developed a technology called iAdapt Responsive Cleaning Technology.,Roombas rely on a few simple algorithms such as spiral cleaning (spiralling), room crossing, wall-following and random walk angle-changing after bumping into an object or wall. This design is based on MIT researcher and iRobot CTO Rodney Brooks' philosophy that robots should be like insects, equipped with simple control mechanisms tuned to their environments. The result is that although Roombas are effective at cleaning rooms, they take several times as long to do the job as a person would. The Roomba may cover some areas many times, and other areas only once or twice. The Virtual Wall accessories project infrared light beams which the Roomba will not cross. Newer model Scheduler Virtual Walls can be set up to turn on via IR at the same time a Roomba is activated. As Virtual Walls are battery-powered, this is desirable to avoid wasting power projecting IR beams when not needed.

The Roomba is not designed for deep-pile carpet. Also, the first- and second-generation Roombas can get stuck on rug tassels and electrical cords. The third-generation is able to reverse its brushes to escape entangled cords and tassels. Additionally, all models are designed to be low enough to go under a bed or most other items of furniture. If at any time the unit senses that it has become stuck, no longer senses the floor beneath it, or it decides that it has worked its way into a narrow area from which it is unable to escape, it stops and sounds an error to help its owner find it. Early models use only flashing lights to indicate specific problems, while later models use voice synthesis to announce a problem and a suggested solution.

General maintenance of the Roomba consists of emptying the debris bin and cleaning the dust filter, as well as removing and cleaning the brushes. Excessive hair accumulation in the brush system can cause the brushes to stall, or overload the brush motor, damaging the unit. Lesser amounts of hair build-up will merely slow down the brushes, reducing cleaning effectiveness and battery life. Special "pet-friendly" options and models are available, which are supposed to be more resistant to hair build-up, and easier to clean.

C. BATTERY-LIFE AND RELIABILITY

Battery reliability is a frequently-mentioned complaint on the iRobot, Amazon, and other third-party customer review websites. Battery replacements from iRobot cost a significant fraction of the purchase price of a new Roomba, though compatible third-party batteries are available at a lower price. The iRobot customer support website offers advice on maximizing battery performance and longevity. All batteries will gradually lose energy capacity, resulting in shorter cleaning runs, eventually necessitating replacement. Roomba batteries are end user replaceable within minutes.

When a Roomba owner is absent for an extended period (such as a vacation or due to illness), automatically scheduled cleaning runs should be cancelled. For example, if it becomes entangled and stops with an error sound on an unattended session, the battery will remain deeply discharged for an extended period, often resulting in permanent damage to the battery.

D. ACCESSORIES

1) Easy Clean Brush — A brush that is designed specifically for cleaning pet hair, being easier to clean off (standard on models designated "for pets").
2) Remote Control — Allows the owner to remotely operate basic Roomba functions (works with all second- and third-generation Roombas).
3) Wireless Command Center — Allows the owner to remotely operate most Roomba functions, including scheduling (works only with certain third-generation Roombas).
4) iRobot Scheduler — Allows the owner to program the Roomba to clean at certain times automatically. The "Schedule Upgrade" accessory will also update a pre-2.1 Roomba to the 2.1 software (for second-generation Roombas).
5) Homebase — The Roomba automatically returns to and docks here for recharging (for second- and third-generation Roombas).
6) Virtual Wall — Used for keeping the Roomba out of designated areas.
7) Virtual Wall Lighthouse — Functionality of Virtual Wall with an additional "Lighthouse" mode, which will contain Roomba in one room until the room is completely vacuumed before moving on to the next. As of 2012, iRobot has sold at least 5 different Virtual Wall designs, with different cases and capabilities.
8) Virtual Wall Halo — Designates a circular zone 20" (50 cm) in diameter to protect small items, like pet water and feeding bowls, from being disturbed by a Roomba
9) OSMO — A temporary dongle that attaches to the serial port on the Roomba to update a pre-2.1 Roomba's firmware to version 2.1; this also can correct the "circle dance" problem (for all second-generation Roombas).
10) Advanced Power System (APS) Battery — Higher-performance rechargeable battery for all models that holds enough power to clean for 200 minutes.
11) Roomba Serial Control Interface (Roomba SCI) — Exposes all the functionalities and sensor information from the iRobot Roomba vacuum cleaner for external interfacing. Using the SCI, aroboticist can command

and control the Roomba by connecting to the 7-pin Mini-Din UART port.

12) Roo series of accessories, by RoboDynamics
    a. RooTooth — A Bluetooth module that converts the Roomba to Bluetooth control from any bluetooth device.
    b. RooStick — Allows programming input through a USB interface.
    c. Roo232 — Allows programming input through a serial port connector.
13) RoombaFX — A C# class by RoboDynamics that implements the entire Roomba SCI command set. Available on Source Forge for download and user contributions

V. MODELS IN MARKET

1) FIRST GENERATION

Introduced in 2002, the first-generation Roomba[8] had three buttons for room size. The first-generation units comprise the original, silver-colored Roomba, the blue Roomba Pro, and the maroon Roomba Pro Elite. The latter two models included additional accessories, but all three use the same overall core robot and cleaning system.

Figure 3: First generation Roomba

2) 400 SERIES

The second-generation Roombas (dubbed "Discovery", later called "400 series") replaced their predecessors in July 2004, adding a larger dust bin, better software that calculates room sizes, dirt detection and fast charging in the home base (or wall hanger in the case of the Discovery SE). All second-generation Roombas are functionally identical, though some have more or fewer buttons, accessories, or different external designs[9]. Version "2.1" contained updated software and a new front wheel. Version "2.1" was issued in 2005, and the update was made available to existing units as well. The low-end models continued to be available after the introduction of the 500-series with new, three-digit model names.

Figure 4: Second Generation Roomba

Roomba budget models (Dirt Dog and Model 401) have a simplified interface (a single "Clean" button) and lack some of the software-controlled flexibility of other versions. They are positioned to be less-expensive versions of the Roomba for first-time purchasers. The Roomba Dirt Dog contains sweeping brushes and a larger dust bin, but lacks the vacuum motor. It uses the space that would be required for the vacuum for additional dust bin volume. It was designed for home shop or home garage environments.The Dirt Dog was discontinued in 2010. The Roomba Model 401 is similar but has a "standard" size dust bin and vacuum system. Budget models are upwards-compatible with the extended-life batteries, fast charger and schedulers of the 400 series.

3) 500 SERIES

The third-generation 500 series Roomba was first introduced in August 2007, and features a forward-looking infrared sensor to detect obstacles and reduce speed, a "Dock" button and improved mechanical components & smoothness of operation.It also introduced customizable decorative face plates. The Roomba 530 came with two Virtual Walls and a recharging dock.

4) 600 SERIES

The 500 series have been superseded by the 600 series in August 2012. All models come with the AeroVac bin and the Advanced Cleaning Head.

5) 700 SERIES

In January 2011, iRobot announced the Roomba 700 Series robots. Although largely similar to the 500 series, the 700 series features a number of improvements. Among these are a more robust cleaning system, improved AeroVac bin with HEPA filter and improved battery life.

Figure 5: 700 series Roomba

Like the 500 series, the 700 series[10] includes robots with different technologies and accessories. The Roomba 760 is the simplest of the robots, and Roomba 790 is the newest and most advanced with both scheduling and a large range of accessories including Lighthouses, Wireless Command Center and extra brushes and filters. Besides these two models, also Roomba 770and 780 are available – both with scheduling, DirtDetect 2 and full bin indicator.

The updated models started shipping in May 2011.

VI. LIST OF MODELS

A . 2002+

The first generation[11]:

- Roomba (2002, improved in 2003, discontinued)
- Roomba Pro (2003, discontinued)
- Roomba Pro Elite, model # 3100, (2003, discontinued)

The first-generation Roombas have three buttons for room size.

B. 2007+

- Roomba 510
- Roomba 530
- Roomba 532 (similar to a 530, with enhanced components for pets)
- Roomba 535 (HSN Version)
- Roomba 550 (Costco Version, 540 Costco Canada Version)[33]
- Roomba 560
- Roomba 562/564 (like a 560, with enhanced components for pets)
- Roomba 570/571
- Roomba 572 (like a 570, with enhanced components for pets, 572 Costco Canada Version)
- Roomba 580/581 (580 released in August 2007)
- Roomba 610 (Roomba PRO)

C. 2012+

The 500 series have been superseded by the 600 series in August 2012. All models come with the AeroVac bin and the Advanced Cleaning Head:

- Roomba 620 - Basic model
- Roomba 630 - Includes an Auto On virtual wall
- Roomba 650 - Auto On virtual wall, scheduler.
- Roomba 660 - Auto On virtual wall, scheduler, iAdapt.

D. 2013+

The 600 series now superseded by the 700 series which ran alongside the 600 series for a period of time in 2012. There are several models in the 700 series:

- Roomba 760 - Base model
- Roomba 770 - As 760 but includes - Dirt Detect Series 2 Technology and Full Bin Detection
- Roomba 780 - As 770 but includes - Room-to-room navigation, Capacitive Touch Control panel and Virtual Wall Lighthouses (which replace Auto Virtual Walls)
- Roomba 790 - As 780 but includes - Wireless Command Center, 3 Virtual Wall Lighthouses and Storage Case
- Roomba 880 - As 790 but includes - Batteries all included, 1 Xlife battery, 1 Extra HEPA filter, aerovac tube bin (which adds more into Roomba)

VII. METHODOLOGY

A) SPIRAL ALGORITHM

Spiral filling paths cover the area starting from the outside[4] and going towards the centre. In figure 1 a typical spiral pattern is shown. In practically every environment a single spiral cannot cover the entire area and thus multiple spirals need to be made, requiring a procedure like backtracking (going back to places where the robot has been before, but where it found a way to go to a still uncovered area) to ensure complete coverage.

The backtracking spiral algorithm mentioned is an example of an approximate cellular decomposition. In the algorithm is improved to also handle the covering of cells within this grid that are partially covered by an obstacle (BSA a coarse-grain grid).

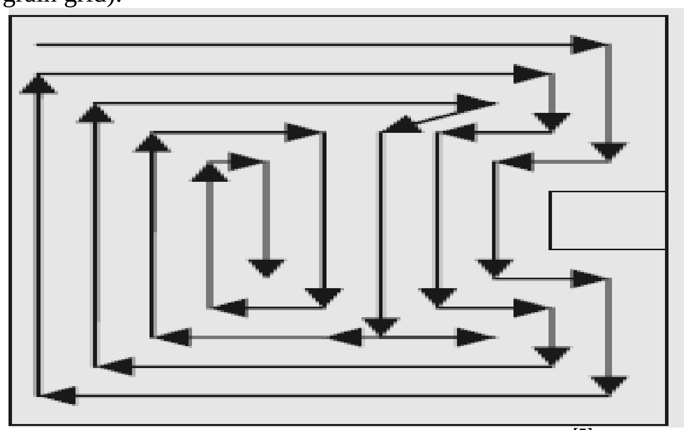

Figure 6: Spiral algorithm of movement[5]

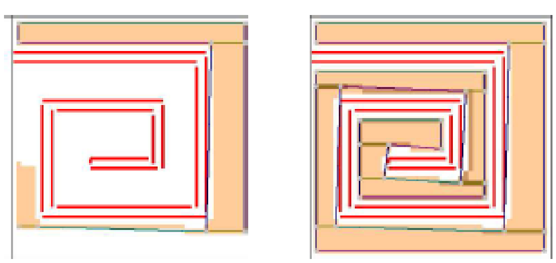

Figure 7: Movement of an object in a spiral

The robot has a circular shape and has a fixed maximum speed. The robot is capable of moving in straight lines and can turn while staying at the same location. Since some of the current randomly moving cleaning robots also meet these specifications, the technology for creating such a robot is readily available. For calculating the covered area we assume that the robot can clean a circular area around its centre. We call this radius the cleaning radius. In this paper the robots cleaning radius is set to 80% of its radius.The robot can receive sensory data by using an infrared range finder. The robot is able to rotate the infrared range finder with a constant velocity relative to its torso.

B) CLEANING AND OBJECT SENSING

While bot is cleaning, it avoids steps (or any other kind of drop-off) using four infrared sensors on the front underside of the unit. These cliff sensors constantly send out infrared signals, and bot expects them to immediately bounce back. If it's approaching a cliff, the signals all of a sudden get lost. This is how bot knows to head the other way. When bot knocks into something, its bumper retracts, activating mechanical object sensors that tell bot it has encountered an obstacle. It then performs (and repeats) the sequential actions of backing up, rotating and moving forward until it finds a clear path.

Another infrared sensor, which is called a wall sensor, is located on the right side of the bumper and lets bot follow very closely along walls and around objects (like furniture) without touching them. This means it can clean pretty close up to these obstacles without bumping into them.

Bot starts cleaning in an outward-moving spiral and then heads for the perimeter of the room. Once it hits an obstacle, it believes it has reached the perimeter of the room. It then cleans along the "perimeter" until it hits another obstacle, at which point it cleans around it, finds a clear path and proceeds to traverse the room between objects like walls and furniture until the allotted cleaning time is up. The idea appears to be that if it cleans for a certain amount of time, it'll cover the whole floor, but whether it actually achieves complete floor coverage is pretty much hit or miss.

C) APPLICATIONS

1) Home automation is one domain that has been target of all robotics companies, large and small. Soon a time could come when you clean your home using a robot just like the one we've given life here. These could make the tiresome task of cleaning all those rooms, into a few minutes work. Cleaning your home would no longer be the same.

2) The robotic cleaner enhances the technology of cleaning and can be further used to integrate features of fast and effective cleaner by different other methods. As we can observe that development of comfort systems has found a new market for themselves and if these systems can be remotely operated, i.e. in the click of just one single button we have an entire smart home for us.

3) Gadgets like these prove instrumental in designing homes having all the facilities, and with the inclusion of more and more features like that, a new sound picture of future begins to develop.

4) Places like hospitals, restaurants and retirement homes can take the advantage of these devices where not much dirt is accumulated and can be cleaned easily with these devices.

VIII. FUTURE SCOPE

As we mentioned in the objectives of this survey, we were able to demonstrate the intended application of the system. This concept has proven to be an efficient way of saving time and helping physically disabled people.

This system is especially beneficial to working women. As specified the user can switch on the device and go for any other work and the robot will automatically clean the floor by detecting and avoiding the obstacles on its way. As the device has a manual mode, the user can also control the robot as per his/her wish.

The microcontroller can be easily used to modify and enhance the various capabilities of any bot, evolving its capabilities to explore new pathways of working efficiently.

Sensors, IR and bump, are effective in movement of bot around cliff and boundaries of the room. These sensors, with, greater resolution can give the correctness of movement to degrees which lead to smooth cleaning of the room.

With advancement in manufacturing technology and computational speed of microprocessors, a swarm of cleaner robot can perform the above mentioned actions. Companies are now releasing scrubber versions of the same breed of domestic robots which can work in tandem if synchronized correctly

GSM modules can be added to the domestic robots making them easy to operate and accessible from any part of the world. The technology seems a bit farfetched and difficult to implement on a great technological level, but the advent of these ideas can lead to a breakthrough in modern domestic robot industry.

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