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Autonomous Vacuum Cleaner with Smartphone Compatibility

N. M. Borkar[1], Pragya Mishra[2], Anjali Mishra[3], Aastha Bisen[4], Tanuj Tiwari[5]
Assistant Professor[1], Student[2, 3, 4, 5]
Department of EC
Shri Ramdeobaba College of Engineering and Management, Nagpur, India

Abstract:
With the new trend of automation which has efficiently taken over almost all fields of domestic and industrial applications, facilitating the new era of time – efficient and accurate methods of achieving high end products. The 'Automated Vacuum Cleaner with Smartphone Compatibility' is another example of high end, low cost automatic home appliance. With 2.5 billion smartphone users all across the world, the product gets exposed to even higher degree of usage convenience when the entire technology is integrated with a widely used familiar device like a smartphone. As compared to the similar functioning devices in the market, the project aims to lower the cost of the product by increasing the accuracy and efficiency of the purpose of the device.

I. INTRODUCTION

In recent years, robotic cleaners have taken major attention in robotics research due to their effectiveness in assisting humans in floor cleaning applications at homes, hotels, restaurants, offices, hospitals, workshops, warehouses and universities etc. Basically, robotic cleaners are distinguished on their cleaning expertise like floor mopping, dry vacuum cleaning etc. Some products are based on simple obstacle avoidance using infrared sensors while some utilize laser mapping technique. Each cleaning and operating mechanism of robotic floor cleaners has its own advantages and disadvantages. For example, robots utilizing laser mapping are relatively faster, less time consuming and energy efficient but costly, while obstacle avoidance based robots are relatively time consuming and less energy efficient due to random cleaning but less costly. Countries like India are way back in manufacturing robotic cleaners. Importing them from abroad increases their costs. The main objective of this work is to provide a substantial solution to the problem of manufacturing robotic cleaner utilizing local resources while keeping it low costs.

II. LITERATURE REVIEW

A robotic vacuum cleaner is an autonomous electronic device that is intelligently programed to clean a specific area through a vacuum cleaning assembly. Some of the available products can brush around sharp edges and corners while others include a number of additional features such as wet mopping and UV sterilization rather than vacuuming. Some of the available products are discussed below.

A. *iRobot*: In 2002, iRobot launched its first floor vacuum cleaner robot named Roomba. Initially, iRobot decided to manufacture limited number of units but Roomba immediately became a huge consumer sensation. Due to its increasedmarket demand, a series of following robots have been launched in the market:

1. Roomba:
• Launch Date: 2002
• Manufacturer: iRobot (American)
• Type of Use: Dry Vacuum
• Technology: IR, RF and auto-charging mechanism
• Price: $500

2. Scooba
• Launch Date: 2005
• Manufacturer: iRobot (American)
• Type of Use: Wet Washing of Floor
• Technology: IR with virtual wall accessories
• Price: $500

3. Braava
• Launch Date: 2006
• Manufacturer: iRobot, KITECH, Sony
• Type of Use: Floor moping for hard surfaces/Dry clean
• Technology: IR with virtual wall accessories for industrial cleaning
• Price: $700

B. NEATO Robotics

With the advent of robotic vacuum cleaners, many countries had started manufacturing robotic cleaners. China also started manufacturing these robots with more reliable technology and advanced features.

1. Neato XV-11
• **Launch Date:** 2010
• **Manufacturer:** Neato-Robots XV series (California)/China
• **Type of Use:** Vacuum Cleaning
•**Technology:**Laser range finder technology, SLAM (Simultaneous localization and mapping) and auto-charging
• Price: $399

C. Dyson

In 2001, Dyson built a robot vacuum known as DC06 which was never released to the market due to its high price. In 2014, Dyson launched a new product named as Dyson 360 Eye which uses a different technology for path finding as compared to products manufactured by NEATO Robotics or iRobot.

1. EYE-360
• Launch Date: 2016
• Manufacturer: Dyson (UK)
• Type of Use: Vacuum Cleaning

• Technology: It uses a 360 degree panoramic vision camera to monitor its environment in real time and a turbo brush for efficient cleaning along with an auto-charging mechanism (Benchmark in history of cleaning robots)
• Price: $1000 (approx.)

III. MECHANICAL DESIGN OF AUTOMATIC VACUUM CLEANER WITH SMARTPHONE TECHNOLOGY

A. Chassis

The base of the body comprises of acrylic sheet, two encoder motors along with Teflon tires having O-rings on them for avoiding friction, two ball casters of adjustable height having frictionless steel balls, aluminum angular brackets and aluminum holders for two lead acid batteries of 12V and 1.2Ah rating. These motorsare independently powered and mounted diagonally and two ball casters are placed at other diagonal of acrylic sheet so that motors can move along its axis easily and bear more weight as compared to chain mechanism. Cleaning assembly includes a DC geared motor, sprockets for moving chain from geared motor to rotating brush and two aluminum rods for supporting vacuum cleaner mechanism and dirt compartment. This DC geared motor has been fitted on one side of acrylic sheet with aluminum holder and sprockets installed with it which have been fitted into shaft of motor. All components are installed on lower side of acrylic sheet so that center of gravity should be lower and robot would be stable.

B. Brushing

Brushing mechanism consists of one rolling brush, steel sheet for cover, two aluminum holders, two ball-bearing and one mild steel strip. One rolling brush mounted on aluminum holders with bearings inside them. This mechanism is attached through mild steel strip to the base of robot. Brush is used to broom the dirt particles into the vacuum chamberin case of carpeted floor for efficient cleaning.

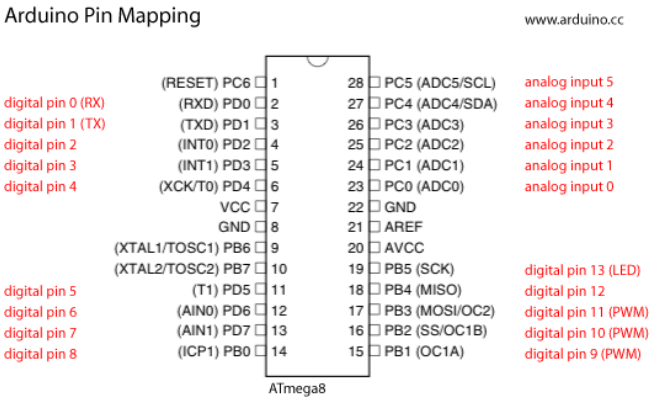
C. Vacuum Cleaning and Dirt Disposal:

Vacuum cleaning and dirt disposal mechanism consists of vacuum motor, propeller, steel holders for fixing motor, filter mounted on two steel rods, aluminum alloy sheet, steel sheet, servo motor, aluminum brackets and aluminum strips. Propeller mounted to a vacuum motor fixed by steel holders and filters are placed on inside of aluminum alloy. Steel sheet has been molded in such a shape that it gave a shape of a robot. Aluminum alloy is also molded into a shape just like steel sheet but of bigger size. Both sheets are attached together results in narrow tunnel from front side and broad compartment at back side. Narrow tunnel is necessary for better suction of dirt and broad compartment is used as dirt compartment.

IV. ELECTRONIC PERIPHERALS

A. ATmega 8

The Atmel®AVR® ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.



The Atmel®AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

B. Motors

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors),or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor. The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. The advantages of a brushless motor over brushed motors are high power to weight ratio, high speed, and electronic control. Brushless motors find applications in such places as computer peripherals (disk drives, printers), hand-held power tools, and vehicles ranging from model aircraft to automobiles. Because the controller implements the traditional brushes' functionality it needs the rotor's orientation/position (relative to the stator coils). This is automatic in a brushed motor due to the fixed geometry of rotor shaft and brushes. Some designs use Hall effect sensors or a rotary encoder to directly measure the rotor's position. Others measure the back-EMF in the undriven coils to infer the rotor position, eliminating the need for separate Hall effect sensors, and therefore are often called sensor - less controllers. A typical controller contains 3 bi-directional outputs (i.e., frequency controlled three phase output), which are controlled by a logic circuit. Simple controllers employ comparators to determine when the output phase should be advanced, while more advanced controllers employ a microcontroller to manage acceleration, control speed and fine-tune efficiency.

C. L298 Motor Controller

Motor controllers commonly known as H-Bridge, are used for driving motors in both direction that is clockwise and counterclockwise with current rating of 15 A. This controller consists of two parts. First part is to energize relays through Microcontroller and drive motors while second part is for

controlling the speed of motors. Relays are used for switching purposes while transistors are used for speed control. Relays used in this circuit have rating of 12V dc coil and 15A current while lead acid battery of a 12V and 1.2Ah rating. Since encoder motors have a stall current of 7A so for safe purpose 15A relays have been used. Two diodes are implemented in fly back diode configuration. This is a condition in which a diode is put in reverse state between battery terminals and is commonly known as free-wheeling diode. At de-energizing of relay huge voltage is produced in backward state and can damaged other components so to avoid this damage a diode in fly back configuration is used along with relay. Pulse width modulation (PWM) is used for speed control. PWM is given totransistor BJT 2N2222 along with some duty cycle to compel motor to start at some intervals resulting in controlling speed. This circuit is powered up through separate battery connected through ON/ OFF switch and fuse to provide protection.

D. Obstacle Sensors

Infrared Obstacle Sensor Module has built-in IR transmitter and IR receiver that sends out IR energy and looks for reflected IR energy to detect presence of any obstacle in front of the sensor module. The module has on board potentiometer that lets user adjust detection range. The sensor has very good and stable response even in ambient light or in complete darkness.

- Operating Voltage: 3.0V – 5.0V
- Detection range: 2cm – 30cm (Adjustable using potentiometer)
- Current Consumption: at 3.3V : ~23 mAat 5.0V: ~43 mA
- Active output level: Outputs Low logic level when obstacle is detected
- On board Obstacle Detection LED indicator

An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo–Coupler or Opto–Coupler. As said before the Infrared Obstacle Sensor has built-in IR transmitter and IR receiver. Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations. Hence, they are called IR LED's. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye. Infrared receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

E. 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. The HC-05 Bluetooth Module can be used in a Master or Slave configuration, making it a great solution for wireless communication. This 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 Bluecore 04- External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature).

1) Hardware Features

- Typical - 80dBm sensitivity.
- Up to +4dBm RF transmit power.
- 3.3 to 5 V I/O.
- PIO (Programmable Input/output) control.
- UART interface with programmable baud rate.
- With integrated antenna.
- With edge connector.

2) Software Features

- Slave default Baud rate: 9600, Data bits: 8, Stop bit:1,Parity:No parity.
- Auto- connect to the last device on power as default.
- Permit pairing device to connect as default.

The Bluetooth module HC-05 is a MASTER/SLAVE module. By default the factory setting is SLAVE. The Role of the module (Master or Slave) can be configured only by AT COMMANDS. The slave modules cannot initiate a connection to another Bluetooth device, but can accept connections. Master module can initiate a connection to other devices. The user can use it simply for a serial port replacement to establish connection between MCU and GPS, PC to your embedded project, etc. Just go through the datasheet for more details.

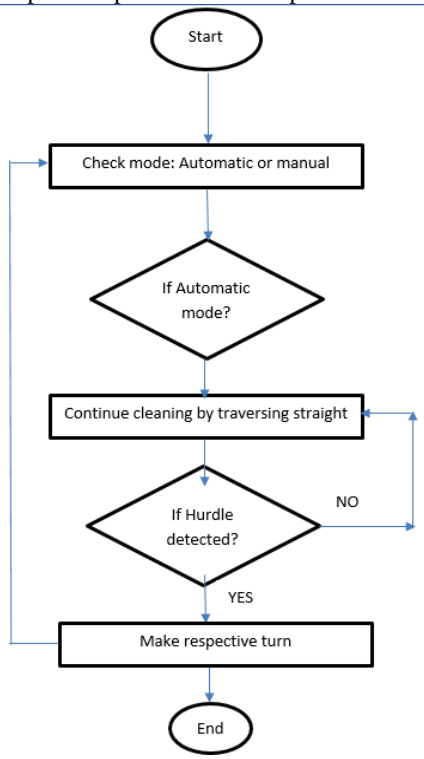
F. BATTERY

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smartphones, and electric cars. When a battery is supplying, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that when connected to an external circuit will flow and deliver energy to an external device. When a battery is connected to an external circuit, electrolytes are able to move as ions within, allowing the chemical reactions to be completed at the separate terminals and so deliver energy to the external circuit. It is the movement of those ions within the battery which allows current to flow out of the battery to perform work. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved additionally to include devices composed of a single cell. Primary (single-use or "disposable") batteries are used once and discarded; the electrode materials are irreversibly changed during discharge. Common examples are the alkaline battery used for flashlights and a multitude of portable electronic devices. Secondary (rechar geable) batteries can be discharged and recharged multiple times using an applied electric current; the original composition of the electrodes can be restored by reverse current. Examples include the lead-acid batteries used in vehicles and lithium-ion batteries used for portable electronics such as laptops and smartphones.

V. WORKING

The autonomous vacuum cleaner robot has a specific cleaning methodology. The methodology used in this proposed autonomous vacuum cleaner robot is to achieve the objective of cleaning the floor with less power consumption. It can operate in two modes: the autonomous mode in which it traverses a path that repeats itself in parallel and the manual mode which makes use of the Bluetooth module HC-05 to make wireless communication with the user. In the autonomous mode, the robot is initially placed in the left corner of a room adjacent to a wall and then traverses a straight path with both the rear wheels

moving along with the front dummy wheels. When it encounters an obstacle (a wall), the robot is programmed to reverse its right wheel and operate only the left wheel to make a right 90 degree turn. It moves a very small distance and again makes a right 90 degree turn. After making these two turns, the robot is now facing the opposite direction with a 180 degree direction reversal. It then traverses a straight path again until it encounters an obstacle (a wall). This time, the robot halts its left wheel and operates its right wheel alone to make a 90 degree turn. It repeats the same operation after traversing a small distance. This is how the robot traverses the parallel path track. Unlike the spiral path which makes its way from the area walls to the center of the area spirally, the parallel path track is simpler and more efficient.



In the manual mode, the robot shall be operated by the user's commands. The basic left, right, forward and backward commands are available to the user. The manual mode operation involves communication between the user and the machine via the Bluetooth module HC-05. An android app takes care of the graphical interface that the user enters the commands and accordingly transmits the signal to the Bluetooth module mounted on the robot.

VI. CONCLUSIONS

This paper highlights a better and simpler approach in providing an overview of the design of an autonomous vacuum cleaner robot. This robot is designed to have all the features of a conventional vacuum cleaner. It can work automatically and manually. The robot can be made useful in large areas of coverage such as hospitals, industries, schools, etc. It can also be used where cleaning involving humans may be harmful.

VII. ACKNOWLEDGEMENTS

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