Autonomous Smart Floor Cleaning Robot (CLEANER)

Kuldeep Soni
Department of Electronics & Communication
Vivekananda Institute of Technology, Jaipur
Jaipur, India

Abstract: **With the advance technology of robots are getting more attention of research to make life of mankind comfortable. This paper presents the design, development and fabrication of prototype Smart Floor Cleaning Robot (CLEANER) using IEEE Standard 1621 (IEEE Standard for User Interface Elements in Power Control of Electronic Devices employed in Office/Consumer Environments). Subject robot operates in autonomous mode as well as in manual mode along with additional features like scheduling for specific time and bag less dirt container with auto-dirt disposal mechanism. This work can be very useful in improving life style of mankind.**

Keywords—Autonomous roaming, manual control, power status indications, power controls, power efficient, cleaning robot.

I. INTRODUCTION

In recent years, robotic cleaners have gained lot of popularity in field of robotics research. Due to there vast usage in assisting humans in floor cleaning application at home, hotels, restaurants, offices, hospitals, workshops. Some of the advantages of operating mechanism are less time consuming and energy efficient but on the other hand it can be less energy efficient due to random cleaning process .The main objective of this work is to provide a optimum solution to the problem of manufacturing robotic cleaner utilizing local resources while keeping it low costs.

In this work, "smart floor cleaning robot (CLEANER)" has been designed for consumer/office environments and its each component in accordance with IEEE Standards. Proposed design is being operated in dual modes. In one of the modes, the robot is fully autonomous and making decisions on the basis of the outputs of infrared sensors, ultrasonic sensors and tactile sensors after being processed by Arduino controller and control the actuators 2 DC encoder motors by the H-bridge driving circuitry. In manual mode, the robot can also be used to clean a specific area of a room by controlling it manually from laptop with a Graphical User Interface (GUI) in Visual Studio (C# programming language) via Bluetooth connectivity.

The mechanical design of robot including chassis design, brushing, vacuum cleaning and dirt disposal mechanism. Electronic circuitry (including motor controllers, vacuum cleaner controller, battery status meters and brushing motor controller along with safety circuit for power supply to sensors, Arduino controller as well as precautionary circuit) is discussed in Section Graphical User Interface (GUI) of the project and robot operation are discussed in Section IV.

II. MECHANICAL DESIGN OF CLEANER

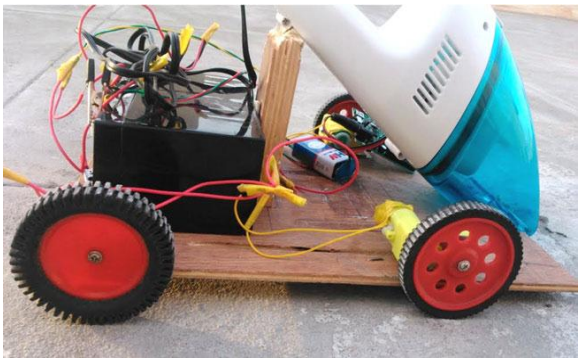

Figure 1 .Mechanical Design of CLEANER.

Mechanical body consists of four parts i.e. chassis, brushing, vacuum cleaning and dirt disposal mechanism. Combination all these four parts makes a complete prototype for testing, as shown in Figure 1.

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 1.2Amp rating. These motors are 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 more weight as compared to chain mechanism. Cleaning robot 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 fitted on one side of acrylic sheet with aluminum holder and sprockets installed with it which have been fitted into shaft of motor. All desired 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 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 chamber in case of carpeted floor for efficient cleaning.

C. Vacuum Cleaner and Dirt Disposal

Vacuum cleaner 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 on 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 gives a shape of a robot. Aluminum alloy is also molded into a shape just like a steel sheet but of bigger size. Both sheets are attached together results in narrow tunnel from front side and broad compartment at back side. Tunnel is necessary for better suction of dirt compartment is used. At very last end of both sheets there is an aluminum strip controlled by servo motor installed at upside of aluminum alloy right behind vacuum cleaner to dispose of dirt. Vacuum Cleaner holder is spot welded on inner side to support 18.1V, 5AhLiPo battery.

III. ELECTRONIC CIRCUITRY

All circuits are designed and simulated in Proteus software. After optimization of values for components, circuits were implemented on PCB. There are five main circuits including three batteries being used in this project and all these circuits are designed, analyzed and then implemented in accordance with IEEE Standard 1621. Explanation of all these circuits is given below:

A. Motor Controllers

Motor controllers known as H-Bridge, are used for driving motors in both direction that is clockwise and counterclockwise with current rating of 15A. This controller consists of two parts. First part is to energize relays through Arduino controller and drive motors while second part is for controlling the speed of motors. Relay is 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 small 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. Pulse width modulation (PWM) is used for motor control. PWM is given to transistor BJT 2N2222 along with some duty cycle motor to start at some intervals resulting in controlling speed. This power to the circuit is provided by separate battery which is connected through ON/ OFF switch and fuse to provide protection and a Red LED glowing if the circuit is disconnected owing to section: 4 of IEEE Std. 1621.

B. Vacuum Cleaning Controller

This circuit used for controlling of vacuum cleaner consists of one transistor, one relay, one diode and two batteries. One Lead acid battery of 12V and 1.2Ah ratings is for power controlling (ON/OFF) of vacuum cleaner by energizing coil of relay having diode in a fly back position while one LIPO battery of 18V and 5Ah is used for supplying power to vacuum cleaner with different ground terminals to avoid short circuit currents. Signal from Arduino controller is given to transistor BJT 2N2222 which energizes relay and relay switches. After switching relay will allow 18V power supply through it and turns on vacuum cleaner through an ON/ OFF switch. This circuit is properly insulated to provide safety since currents may exceed to 7A.

C. Battery Meters

This circuit consists of two buffer ICs, six colored LED's (3-Red & 3-Green) indicating battery power status and four resistors for voltage divider. Positive terminal of battery is connected to one resistor and output taken from second resistor gives a fixed voltage that fixed voltage goes to buffer IC so no current should be drawn from circuit. The fixed voltage of buffer IC goes to Arduino where it is programmed and processed results in turning ON/OFF of LED's showing whether battery is charged or discharged depending on value of voltage being fed into Arduino. Resistors should have values in kilo ohms so that current would be in milli amperes to meet the offset of buffer IC. If resistors of high values in mega ohm used then current will be in micro amperes and buffer IC offset will not reached and IC would not be in working state.

D. Brushing Motor Controller

The circuit consists of two transistors. One transistor take signals from Arduino controller and drives other transistor. Transistor which takes a signal from BJT 2N2222 and other one is TIP-122. Circuit of motor controller works on 12V DC supply connected through a switch and fuse. Two transistors are used but transistor TIP- 122 has high current rating and cannot be activated by Arduino directly. Transistor BJT 2N2222 is not used only because current of brush motor is much high and BJT will not provide necessary current. Combination of these two transistor gives a successful circuit to drive brush motor.

E. Power Supply to Sensors

All sensors are used at 5V but batteries are of 12V and 18V. Regulator IC 7805 is used for converting 12V to 5V with current in milli amperes range. Capacitors are also used for voltage regulation and if there is some impulse which can disconnect power to sensors then these capacitors will act as source for maintaining connection to sensors. In case of disconnected state of power supply to sensors, White LED glows labeled as disconnected owing to section: 3.1.14 of IEEE Standard 1621.

F. Precautionary Circuit

This circuit consisting of bridge rectifiers, relays, transistors, diodes, fuses, Positive voltage adjustable regulator, LEDs, terminal blocks, and slim headers. This circuit consists of three parts. One is for motor battery safety and regulation of voltage, second for circuit battery voltage safety and third is for controlling motor battery through circuit battery and giving power to Arduino controller. In first part we are consisting, one relay with diode in fly back mode, one transistor, one fuse, terminal blocks, one regulator and variable resistor are used. Bridge rectifier is used to keep the supply voltage positive and secure the circuits if the battery terminals are connected in positive or negative direction. The Signal from Arduino controller is given to transistor

BJT 2N2222 which energizes relay and relay will allow motor voltage to go to fuse from rectifier and then it will go to regulator input. LM338k is used which is positive adjustable voltage regulator having a rating of 15A and can regulate voltage from 12V to 6V. After adjusting voltage at 12V output will be shorted with terminal block and that block is now used for battery output both for encoder motors and brush motor. For more safety, fuse holders are used so that if there is any shot circuiting occurs then it will not harm other components and fuse can easily be changed. Fuse is used of 10A rating as stall current for encoder motor is 7A and for brush motor stall current is 5A. LED along with resistor is placed just after regulator so that to ensure whether voltage is reaching to output terminal or not. Fuse is used of 2A because there is no component which drew more than 800 mA current. 7809 regulator is also used for giving power to Arduino through slim header. Signal from Arduino given to transistor BJT 2N2222 energizes relay connected to motor battery circuit. .

IV. GRAPHICAL USER INTERFACE (GUI)

The main purpose of the GUI is give to all controls in the hand of user, so that he can use this product according to his needs. The software used for the programming of GUI of this device is Visual Studio 2012. As discussed, the robot can be used in manual mode as well as autonomous mode. Selection of the mode can be done from this GUI. Visual Studio receives the data from COM port and displays it on the GUI after decoding. However, the communication via Bluetooth is 2-way i.e. it sends some data as a delivery report. The terms, indicators and labels used in GUI for power controlling and management are employed under sections: 4.3-4.6 of IEEE Std. 1621. A photograph of GUI for smart floor cleaning robot (CLEAR) is shown in Figure 2.

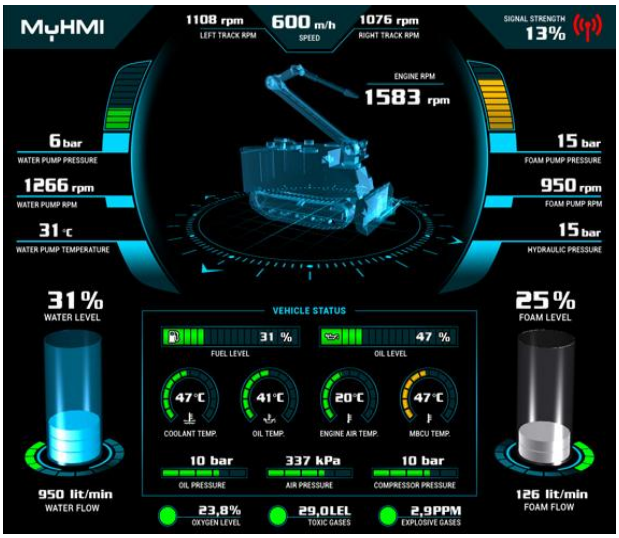

Figure 2. Graphical User Interface (GUI) for 'CLEANER'

The significance and usage of different parts of the GUI are discussed below:

A. Battery Status

Batteries are the most important element in a robot because it provides the power source to all electronic components. In order to divert the attention of the user towards battery status, the display of the battery starts blinking when the battery is less than 20% owing to sections: 4.1 & 4.2 of IEEE Std. 1621. A picture of battery status is shown in Figure 3.

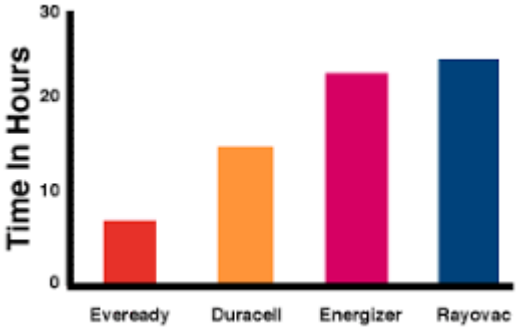

Figure 3.Battery status.

B. Vacuum ON / OFF Button

An ON/ OFF button specify the control of Vacuum Pump unit given in GUI. This button works exactly similar to Brush button. However, these both buttons do not affect working of each other at any instant.

C. Selection of Gears

These gears are similar to automatic automobiles in order to efficiently manage battery power, increase its operating time and control speed according to the needed. The gear selection can be viewed in Figure 4.

Figure 4.Gear selection controls.

1. Parking (P):

It keeps the device in sleep mode in which all the circuitry of the device is switched off. However, the Arduino board and the Bluetooth module are still active, till the device can respond to any command received from the user interface in the laptop.

2. Reverse (R):

It is reverse gear, in which both motors are moves in the reverse direction. As discussed before, motor- controllers are used for changing the direction of rotation of motors. This motor control the feasibility of speed using Pulse Width Modulation (PWM). A tone is introduced in case of reverse motion as mentioned by section: 4.5.3 of IEEE Std. 1621.

3. Neutral (N):

Neutral gear works as a intermediate gear in which the robot is not moving in any direction but still the circuitry is switch ON, waiting for the command from the user. It is to be noted that the brush motor and vacuum pump can be kept ON in this state of the device.

4. Drive (D):

Drive gear is used for forward gear with full speed of the motor. The motors are synchronized using PWM in the motor-controllers, so that both tires rotate at equal speed. The synchronization of the motors in this way makes the robot move exactly in the forward direction without any tilt in any other direction.

5. Low Gear (L):

Low gear is designed for optimum cleaning of the floor. In this gear, the robot moves in half of its full speed. However, the brush motor and vacuum pump work at the same speed, so net cleaning efficiency of the device is increased to the double of its normal efficiency.

V. DISCUSSION ABOUT ROBOT OPERATION

The objective of this project is to make a vacuum cleaning robot which is fully autonomous and manual featured with user friendly interface. The vacuum cleaner is able to clean, brush and auto dispose-off. The robot named as CLEANER it has variable speed and power efficient. CLEANER can be used in autonomous and manual modes as user's input. Customers are provided with the user friendly interface to operate the robot without any difficulty. CLEANER most importantly consumes extremely low energy which is 90W and take lead from the competitors. And it has the safety circuit which rectifies different poles and restricts high voltage to affect the circuitry. This robot also can't do wet cleaning. These two functions can be included in future enhancements of this robot. The evaluation shows that our product is reliable and cost effective. It works with less energy consumption. The results showed that users from the university found no difficulty in using the product. Its results also showed that this product is user-friendly in both modes.

VI. CONCLUSIONS

This paper shows the implementation of IEEE Standard 1621 IEEE Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments in terms of smart floor cleaning robot. The paper shows a better and simple approach to provide an overview of design of a simple robotic cleaners control design using gadgets and instruments. This robot (CLEANER) is specially made on the basis of modern technology. CLEANER has all the features which are required for a vacuum cleaner. It can work automatically and manually. It has the feature auto drain itself. CLEANER has many competitors who are selling same product in high prices. This is first locally manufactured smart vacuum cleaner with all features up to the standards of IEEE. Its scheduling feature which can be operated with computer only, android and windows app. The target audience with all the features is middle and upper class of Pakistani community. It can also be used in the industries where cleaning with the help of human is toxic, vacuum cleaner can easily be used.

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