Autonomous Robotic Floor Cleaner

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Abstract

This paper presents the technological advantages that would help in daily choses of cleaning. For the convenience of most of the people who are extremely busy in these choses, the need of the project has come up. Thus, this has resulted in coming up with an objective of making an autonomous cleaning machine. It is designed to build an autonomous floor cleaning robot that can move itself without continuous human guidance. This cleaner is electro mechanical machine with ultrasonic sensor and IR sensors. Ultrasonic sensor is used for obstacle detection and a pair of IR sensor is used for detecting the surface below the robot without falling down. The proposed system has two main sections for cleaning, Vacuum section and Mopping section. Vacuum section consists of a broom which is attached to the robot to scratch the floor and a vacuum pump is used for sucking the dust particles on the way. Mopping section consists of the water pump with container and the mopped roller. Water pump drips the water on the floor and roller is mopped to clean the floor. All hardware and software operations are controlled by Arduino ATmega2560 microcontroller. This robot can perform dust sweeping and mopping simultaneously. Solar panel is used to charge the power to 12V battery and it is the power source for this proposed cleaning robot. L298N motor driver is used to drive the gear motors and relays are used as switches the motor driver, vacuum cleaner and water pump. The user can set the time to clean the floor for a specific space as it is consisted of the timer function. After fulling the timer, the cleaning process is automatically stop by switching the relays in this system and buzzer is turned on to activate the alarm to the user. This cleaning robot is very useful in improving life style of mankind.

Keywords: Arduino ATmega2560, Solar panel, Robotic floor cleaner, Ultrasonic sensor, Infrared sensor, Motor driver (L298N), Motors, Relay

1. Introduction

Robot is an electromechanical machine and used various purposes in industrial and domestic applications [1]. The basic manual cleaning tool, broom is the most common tool used to clean the floor in house and offices. Cleaning staffs, maids and servants are employed for this duties. However, the use of a broom is not efficient in cleaning the surface and also time consuming. There is a risk of safety especially in households where there are elderly people or housewives and kids [2].

Cleaning robot is a type of mechanical and electrical product for sweeping, dusting and mopping. It is superior to an ordinary vacuum because it is more convenient to use and it can save more time when it works. The whole cleaning process doesn't need a person to control and it reduces the burden on the operation. The noise is smaller than the general vacuum cleaner when it is working. It can purify the air; adsorb harmful substances in the air with activated carbon in it. Its structure is compact, balance and lightweight, but it can clean up some special space. In short, cleaning robot is combined with robotics technology and dust sweeping project and it is intelligent and convenient. So it is an environmentally friendly, healthy, intelligent service robot with a good prospect and a wide range of market demand [3, 4].

A cylindrical brush is used as the broom and in front of the robot to scratch the floor and it sweeps garbages into the dustbin in the process of movement being the vacuum cleaner with the dustbin in this cleaning robot. And the water pump is on the robot and a mopped roller is at the back of the robot. Water pump drips the water on the ground and roller mops the wet floor when the robot is working. Thus, this cleaning robot can perform dust sweeping and mopping simultaneously. This cleaning robot is very useful in improving life style of mankind.

The main purposes of the project are as follows:

- to clean the floor effectively by using robot without human intervention
- to reduce human power and electricity
- to save person valuable time
- to design a convenient product that can be used to clean the room without much physical effort

2. Methodology

The proposed system is able to do the whole cleaning process automatically. The user has to keep the robot on the place where the cleaning has to be done. As it is an autonomous floor cleaning robot that can move itself without continuous human guidance. Figure 1 illustrates the structure of Autonomous Robotic Floor Cleaner.

This cleaner is electro mechanical machine with ultrasonic sensor and IR sensors. Ultrasonic sensor is used for obstacle detection infront of the robot and a pair of IR sensor is used for detecting the surface beneath the robot that are attached at the left and right sides of the robot not to fall down while the robot is operating. It

can also clean on the table without falling down consisting the surface detector function by using a pair of IR sensors.

The robot consists of two main sections, vacuum and mopping sections. Vacuum section consists of a cyclindrical broom which is attached to the vacuum cleaner and it is in front of the robot to scratch the floor and a vacuum cleaner with dustbin is used for sucking the dust particles on the way. Mopping section consists of the water pump with small tank and the roller to mop the floor. Water pump drips the water on the floor and roller mops to clean the wet floor. Thus, this robot can perform dusting and mopping simultaneously.

The weight and size of the robot's structure are very important to design the proposed system. Moreover, The robot is needed to construct the compact, balanced weight design and the speed of the gear motor must be controlled to clean the floor effectively within a small period. All hardware and software operations are controlled by Arduino ATmega2560 microcontroller.

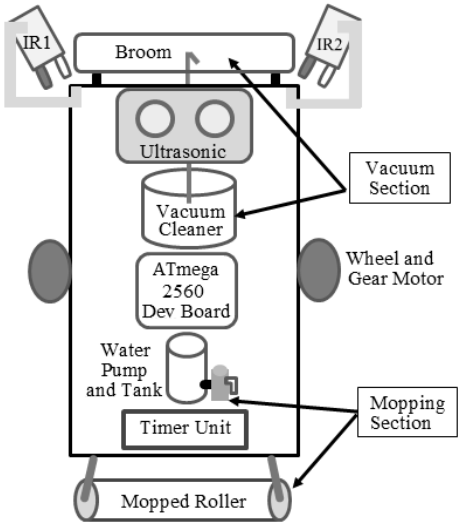

Figure 1. Structure of Autonomous Robotic Floor Cleaner

3. Proposed System Design

This cleaning robot is one of the electro mechanical designs and based on solar power. Solar panel is used to charge the power to 12V, 7.5 Ah lead acid rechargeable battery and it is the power source for this proposed cleaning robot. Charge controller is used between the solar panel and 12V battery as the voltage which is coming from the sun is not constantand is stored in 12V battery. Solar panel is removed while the cleaning robot is operating due to reduce the weight of the robot. Button switch and 4×4 matrix keypad are input system of the timer function and 16×2 LCD is output display system system to display the status of the timer function and cleaning process.

Ultrasonic sensor is used for obstacle detection and a pair of IR sensor is used for surface detecting below the robot. L298N motor driver shield is used to drive the gear motors and relays are used as the switches for the motor driver, vacuum cleaner and water pump. The user can set the time for a cleaning process to clean the floor for a specific space consisting of the timer function in this proposed system design. After fulling the timer, the cleaning process is automatically stopped by switching the relays in this system and buzzer generates a beep sound to activate the alarm to the user.

Arduino mega board, ultrasonic sensor, two infrared sensors, switch, servo motor, relay modules, L298N motor driver shield, 2 gear motors, vcuum cleaner, water pump, 16×2 LCD, 4 × 4 matrix keypad, 5V Buzzer are mainly involved in this psoposed cleaning robot. The block diagram of this system is shown in Figure 2.

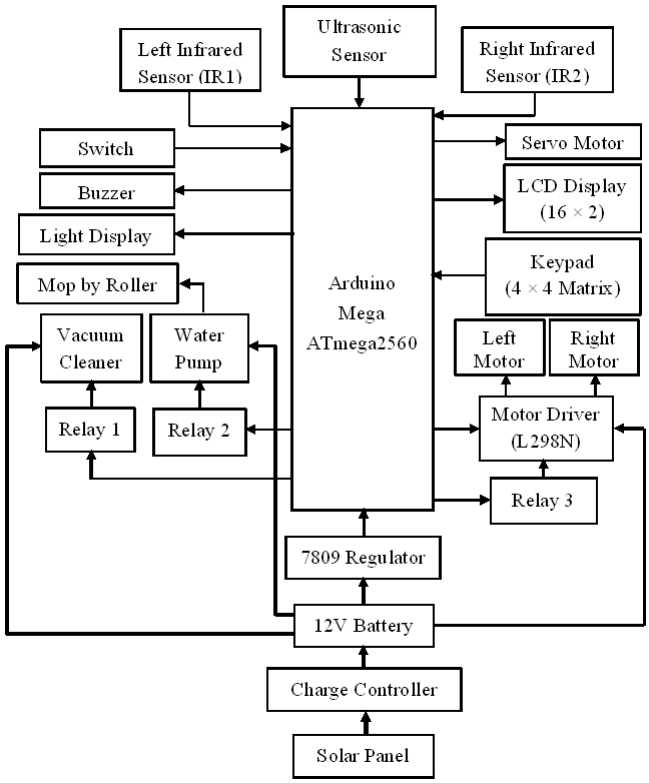

Figure 2. Block diagram of the system

3.1 Hardware Description

Arduino Mega

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins of which 14 can be used as, pulse width modulation, PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. All hardware and software operation of this floor clener are controlled by Arduino Mega 2560 micontroller.

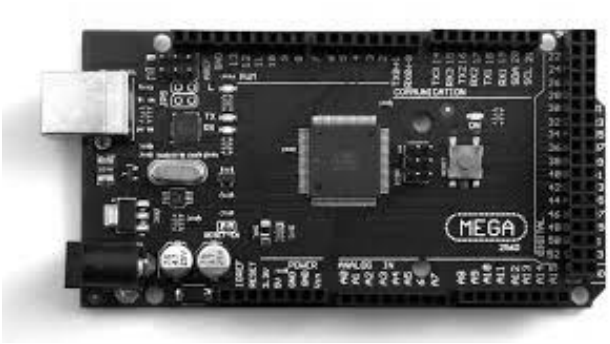

Figure 3. Arduino mega 2560

Figure 5. Ultrasonic sensor

Ultrasonic Sensor (HC-SR04)

This sensor is a high performance ultrasonic range finder. It is compact and measures an amazingly wide range from 2cm to 4m. This ranger is a perfect for any robotic application, or any other projects requiring accurate ranging information. This sensor can be connected directly to the digital I/O lines of your microcontroller and distance can be measured in time required for travelling of sound signal using simple formula as below. Distance = (Echo pulse width high time * Sound Velocity (340M/S)/2) or Distance in cm = (Echo pulse width high time (in us)*0.017) The module works on 5VDC input and also gives an output signal directly for detection of any obstacle up to 4M.Power up the sensor by 5VDC using pins "VCC" and "GND".

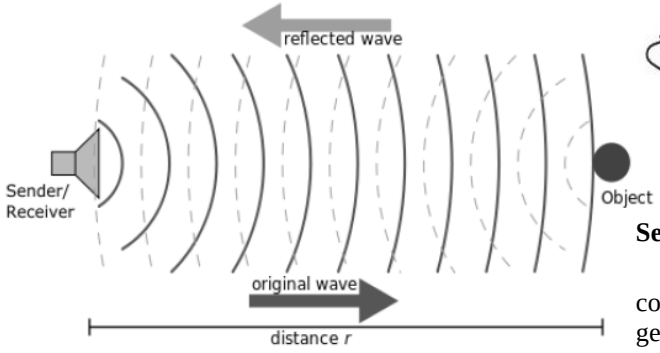

Figure 4. Basic principle of ultrasonic sensor

First of all a 10us trigger input has to be given to the pin named "Trig" on the sensor. This starts one cycle of range conversion and sends 8 bursts of sound waves from the transmitter. As soon as the signals are transmitted the "Echo" pin goes to high level and remains in high level until the same sound waves are received by the receiver. If the received sound waves are same as what the same sensor transmitted then the Echo pin goes to low level. If no object is detected within 5M after 30ms the Echo signal will automatically go to low level. In this floor cleaner, Ultrasonic sensor, HC-SR04 is used to detect the object infront of the robot for avoiding the obstacle while the robot is operating .

Infrared Sensor

The sensor consists of two eyes. One eye sends the infrared light and the other eye sees the reflection of that infrared light and measures the distance which is then sent to the Arduino through analog input to perform further operations based on the distance. There are three wires coming from the sensor .i.e. Red, Black and White or it can be Red, Brown and Yellow. Red is connected to 5V of Arduino. Black or brown to Ground of Arduino. White or yellow to analog input pin of Arduino. A pair of infrared sensors is used to destect the surface below the cleaning robot in this system.

Figure 6. Infrared sensor

Servo Motor

The servo is a kind of position servo drive mainly composed of a casing, a circuit board, non-core motor, gear and the position detector. Its working principle is to steer gear from the receiver or signal the microcontroller, the interior has a reference circuit, the cycle is 20ms, the width of the reference signal 1.5ms, compares the voltage of DC bias voltage was obtained with a potentiometer, voltage difference output. Through the circuit board IC judge the direction of rotation, and then drives the non-core motor starts to rotate, the power is transmitted to the swing arm through the reduction gear, at the same time by the position detector to signal. Applies to those control systems need to angle changing. When the motor speed must, through the reduction gear drive cascading rotary potentiometers, the voltage difference is 0, the motor stops rotating. The rotation angle range of steering gear is 0 degrees to 180 degrees. Servo motor is used and connected with the ultrasonic sensor in this proposed design to change the direction of ultrasonic sensor.

Figure 7. Servo motor

Motor Driver (L298N)

This dual bidirectional motor driver is based on the very popular L298 Dual H-Bridge Motor Driver IC. This module will allow you to easily and independently control two motors of up to 2A each in both directions. L298N motor driver shield is used for driving the gear motors in this floor cleaning robot.

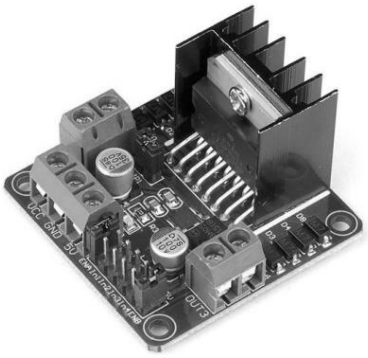

Figure 8. L298N Motor driver shield

Gear Motor

A gear motor is a small motor (ac induction, permanent magnet dc, or brushless dc) designed specifically with an integral (not separable) gear reducer (gearhead). The end shield on the drive end of the motor is designed to provide a dual function. The side facing the motor provides the armature/ rotor bearing support and a sealing provision through which the integral rotor or armature shaft pinion passes. The other side of the end shield provides multiple bearing supports for the gearing itself, and a sealing and fastening provision for the gearhousing. This construction provides many bemefits for a user and eliminates the guesswork of sizing a motor and gear reducer.

Figure 9. Gear motor

LCD

The LCD used here is 16×2 alphanumeric Liquid Crystal Display, LCD which means it can display alphabets along with numbers on 2 lines each containing 16 characters. It is used to display the status about the timer function and cleaning process. It can be used to display the various options and all the readings that have been stored in the EEPROM. 16×2 LCD is used in this system to display the status of the timer function and cleaning process.

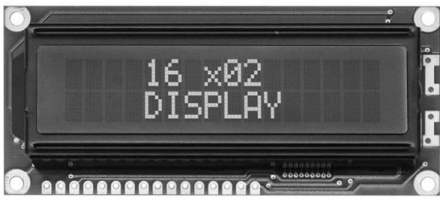

Figure 10. 16×2 Liquid crystal display

4×4 Matrix Keypad

This 16-button keypad provides a useful human interface component for microcontroller projects. Convenient adhesive backing provides a simple way to mount the keypad in a variety of applications. Application areas of 4×4 matrix keypad are as the following:

- Security systems
- Menu selection
- Data entry for embedded systems

In this cleaning robot, it is used as the input system of the timer function to set the time for each cleaning process.

Figure 11. 4×4 matrix keypad

Relay Module

The relay module is an electrically operated switch that allows you to turn on or off a circuit using voltage and/or current much higher than a microcontroller could handle. There is no connection between the low voltage circuit operated by the microcontroller and the high power circuit. The relay protects each circuit from each other. Relay module has three connections named NC, COM, and NO. Depending on the input signal trigger mode, the jumper cap can be placed at high level effective mode which 'closes' the normally open, NO switch at high level input and at low level effective mode which operates the same but at low level input.

Relay module has three voltage pins, Groung, Vcc and Signal which connect to the Arduino. Relay modules are used for switching the motor driver shield and cleaning devices such as vacuum cleaner and water pump.

Figure 12. Relay module

Buzzer

It is an electronic used to give alarm sound as it is programmed. Buzzer is used in this floor cleaner to generate a beep sound when the system is activated after stopping the timer to alarm to the user.

Figure 13. Buzzer

3.2 Software Description

To program the Arduino the Arduino IDE is used which is free software that enables programming in the language that the Arduino understands. In the case of the Arduino, the language is based on C/C++ and can even be extended through C++ libraries. The IDE enables writing a computer program which is a set of step-by-step instructions that is then uploaded to the Arduino. Arduino will then carryout those instructions and interact with whatever it has been connected to it. In the Arduino world, programs are known as "sketches" [5].

4. Implementation of the System

In this proposed system is designed by interfacing the hardware implementation and software implementation.

4.1 Hardware Implementation

Arduino mega ATmega2560 is used as the microcontroller which is connected to power supply (5-12V). This system consists of ultrasonic sensor, a pair of infrared (IR) sensors (IR1 and IR2), 7809 voltage regulator, switch,servo motor, 5V relay module, L298N motor driver shield, two gear motors, vacuum cleaner, water pump, 4×4 matrix keypad, LCD display, buzzer and a pair of LEDs. All the output devices are controlled by arduino and arduino c program is uploaded to the ATmega2560 microcontroller chip in arduino board to control the system. In this project, 12V battery is charged from solar panel. Charge controller is used between the solar panel and 12V battery because the voltage which is coming from the sun is not constantand is stored in 12V battery. But this voltage is more than the required voltage of arduino so that 7809 voltage regulator is used to supply DC 9V to the arduino. Trigger and echo pins of ultrasonic sensor are connected to analog pins A1 and A2 of arduio respectively. Out pin of infrared sensors, IR1 and IR2 are connected pin A4 and A5 of arduino respectively. Digital (yellow) pin of servo motor is connected to pin 10 of arduino. Switch is connected to analog pin A3 of arduino. The schematic diagram of an Aanautonomous Floor Cleaning Robot is shown in Figure 14.

Motor driver shield (L298N) for driving the two motors are connected in such a way that the IN1& IN2 pin of L298N for driving gear motor 1 and IN3& IN4 pin of L298N for driving gear motor 2, these IN1, IN2, IN3 and IN4 are connected to pin 8,7, 6,5 of arduino respectively. OUT1 & OUT2 of L298N are connected to gear motor 1 and OUT3 & OUT4 are connected to gear motor 2. ENA & ENB pins L298N are connected to pin 9 and 4 of arduino respectively.

IN (signal trigger port) pin of 5V relay module is connected to arduino. In this system, three relay modules are used as the switches for L298N motor driver shield, vacuum cleaner and water pump respectively. IN pin of RL1, RL2 and RL3 are connected to pin 22, 23 and 24 of arduino respectively. ABCD and 1234 pins of 4×4 matrix keypad are connected to 34, 35, 36, 37 and 38, 39, 40, 41 respectively. 16 × 2 LCD is connected with arduino and 4-bit mode and used to display the status of the cleaning robot. LCD is interfaced in such a way that RS, E, D4-D7 of LCD are connected to pin 16, 17, 18, 19, 20, 21 of arduino respectively and VCC is connected to 5V and VSS and RW pin are grounded. VEE pin of LCD is connected to terminal pin (2) of POT R2 (10k) which is used to adjust the constrast of the LCD and resistor R1 limits the current through the back light LED. Pin 3 of arduino controls the buzzer which generate a beep sound. And pin 2 of arduino controls a pair of LEDs. Buzzer and a pair of LEDs are activated after fulling the timer for each cleaning process.

4.2 Software Implementation

Arduino IDE, 1.8.3 is used to write the arduino C program to interface to the arduino mega board. Before implementing the proposed system design and hardware circuit is interfaced with the software program of the system by using proteus 8 simulator to simulate the system design of this interfacing circuit.The flowchart of an Autonomous Robotic Floor Cleaner is shown in Figure 15.

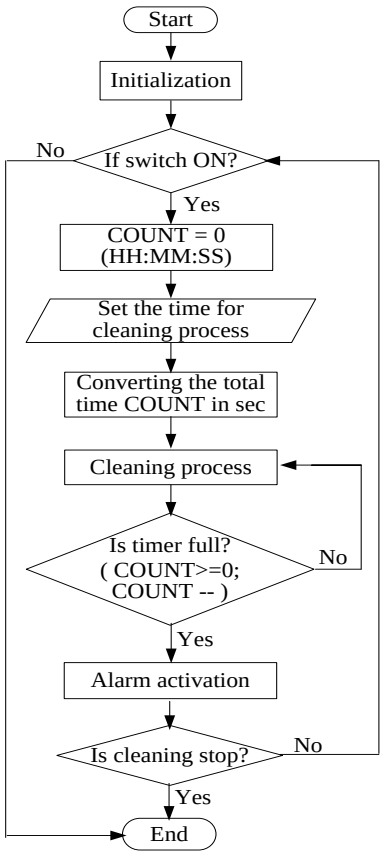

Figure 15. Flowchart of Autonomous Robotic Floor Cleaner

In this system, the output signals from the ultrasonic sensor and infrared sensors are received by arduino but the gear motors and the cleaning devices (vacuum cleaner and water pump) are not operated at the start of the system. As soon as the countdown timer function is started, the cleaning process starts to operate to clean the floor.

The user set count to zero (HH:MM:SS) by pressing the button switch and set the time limit to clen a specific space by using 4×4 matrix keypad. When the countdown timer function is started, Relay 1, 2 and 3 are turned ON and then the cleaning process starts to clean the floor. Relay 1 are used as switch for L298N motor driver to drive the left and right gear motors. Relay 2 and 3 are used as the switches for vacuum cleaner and water pump.

There are two main functions in this cleaning process of floor cleaning robot, these are cleaning devices controlled function and motor controlled function. In cleaning devices controlled function, after relay 2 and 3 are turned ON, the cleaning devices are started to operate and these devices are continued to operate until the end of the countdown timer.

In motor controlled function, as the left and right gear motors are drived by L298N motor driver shield, as soon as the relay 1 is turned ON, the motor driver is also turn ON and then the left and right gear motor are started to operate. The motion of the cleaning robot direction is depended on the received signals of the arduino which is sent by ultrasonic, left and right infrared sensors.

In this system, ultrasonic sensor and a pair of IR sensors are used to move with accurate motion. Ultrasonic detects the object for avoiding the obstacle and a pair of IR sensors detect the surface to avoid falling down. Depending on the input signals received, arduino redirects the robot to move in an alternate direction by actuating the motors which are interfaced to it through a motor driver. The system flow of the robot direction control deign in cleaning process is illustrated in Figure 16.

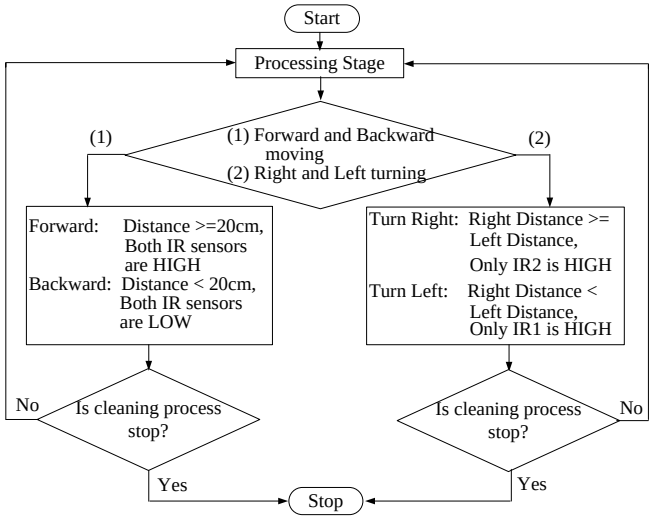

Figure 16. System flow of robot direction control design in cleaning process

In this process, when the object is not detected infront of the robot and both infrared sensors are deteted the surface, the robot moves forward. When the object is detected infront of the robot and both infrared sensors are not deteted the surface, the robot moves backward. When the object is detected in front of the robot, the robot searchs the way and read the distance by ultrasonic sensor to alter the direction of the cleaning robot. If the right distance is greater than and equal to the left distance and only the right IR detects the surface, the robot turns to right. If the right distance is less than the left distance and only the left IR detects the surface, the robot turns to left. After fulling the timer, all the relays are turned OFF and the cleaning process is automaitcally stop. Robot alters its direction according to the output signals from sensors and then continue to move as the direction control design in cleaning process of this system.

5. Result and Discussion

The evaluation of an Autonomous Robotic Floor Cleaner shows it is capable of avoiding the obstacle to prevent collision and also avoiding the edge to prevent falling down by changing robot's position. Not only it can suck the dust and a small piece of rubbish but also mop the floor by using water pump unit to drip water and mopped roller to clean the floor. The cleaning robot has (58 cm) (28 cm) (28 cm) in dimension is very

compact in nature and can go beneath any furniture and bed. And it can be easily move to clean everywhere as it is the portable body design.

Nowadays, cleaning machine roles more improve reducing human power. This system is especially beneficial to working women who has not enough time to do household choses. The user can switch the robot and set the timer for a specific space and go for any other work and the robot will automatically clean the floor by detecting and avoiding both obstacle and edges on its way.

It provides cleaning activities with much more efficiency. It can easily set the period to clean the surface where the user want to clean consisting of timer function. The user can easily know when the cleaning process has been done that the timer is full as the system is activated the buzzer to generate a beep sound in this cleaning robot.

This floor cleaning robot has the lighter body and low cost. It can move smoothly with the steady and slowly motor speed while the cleaning robot is operating and perform to clean the floor effectively within a small period. It can clean for both smooth and rough surfaces. The system flow of the direction control design in cleaning process of the floor cleaning robot is described in Table 1. Figure 17 illustrats the front view of the prototype of Autonomous Robotic Floor Cleaner. Figure 18 and 19 describe the right and left views of the prototype of Robotic Floor Cleaner respectively.

It can not clean where the robot can not enter that place, i.e., the width of the place is narrower than the robot's body or the height is lower than that robot. It have to recharge the battery as it is used DC 12V rechargeable battery.

Table 1. Direction control system of cleaning robot depending on the Inputs

Input			Output				Movement of Robot
Ultrasonic Sensor	Infrared Sensor		Left Motor		Right Motor		
	Left	Right	LM1	LM2	RM1	RM2	
-	0	0	0	0	0	0	Stop
Distance< 20cm	0	0	0	1	0	1	Backward
Right Distance > Left Distance	0	1	1	0	0	0	Turn Right
Right Distance < Left Distance	1	0	0	0	1	0	Turn Left
Distance>=20cm	1	1	1	0	1	0	Forward

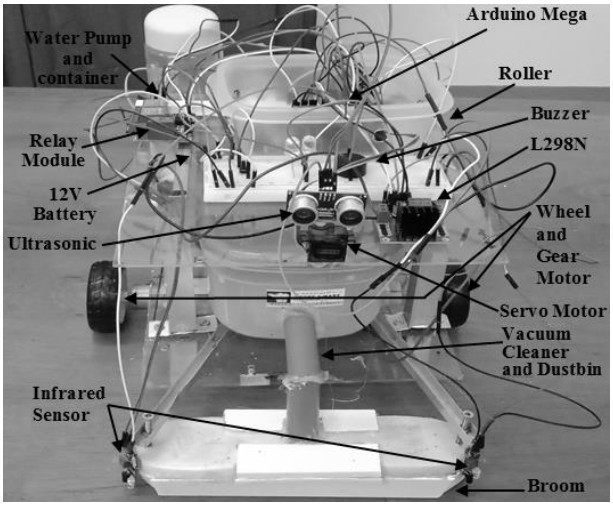

Figure 17. Front view of the prototype of Robotic Floor Cleaner

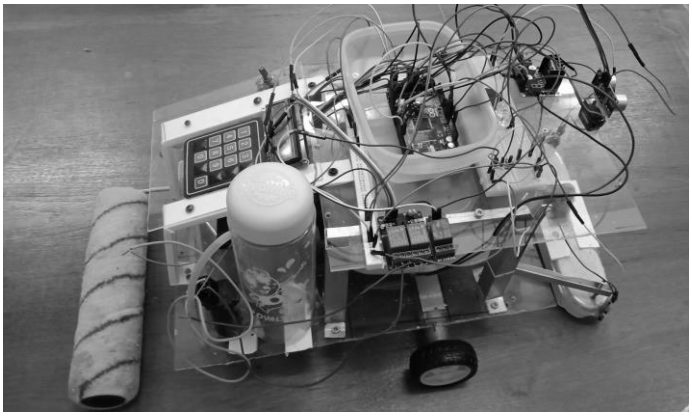

Figure 18. Right view of the prototype of Robotic Floor Cleaner

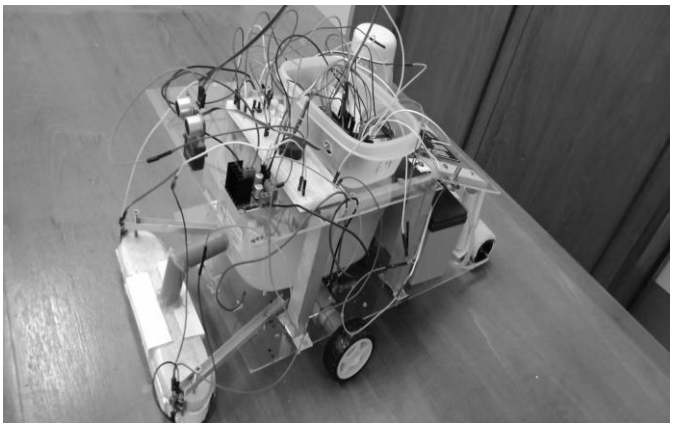

Figure 19. Left view of the prototype of Robotic Floor Cleaner

6. Future Enchancement

The system can be expended to many applications in future.

This project can be extended to set the remote timer using bluetooth module and mobile phone. This system can be

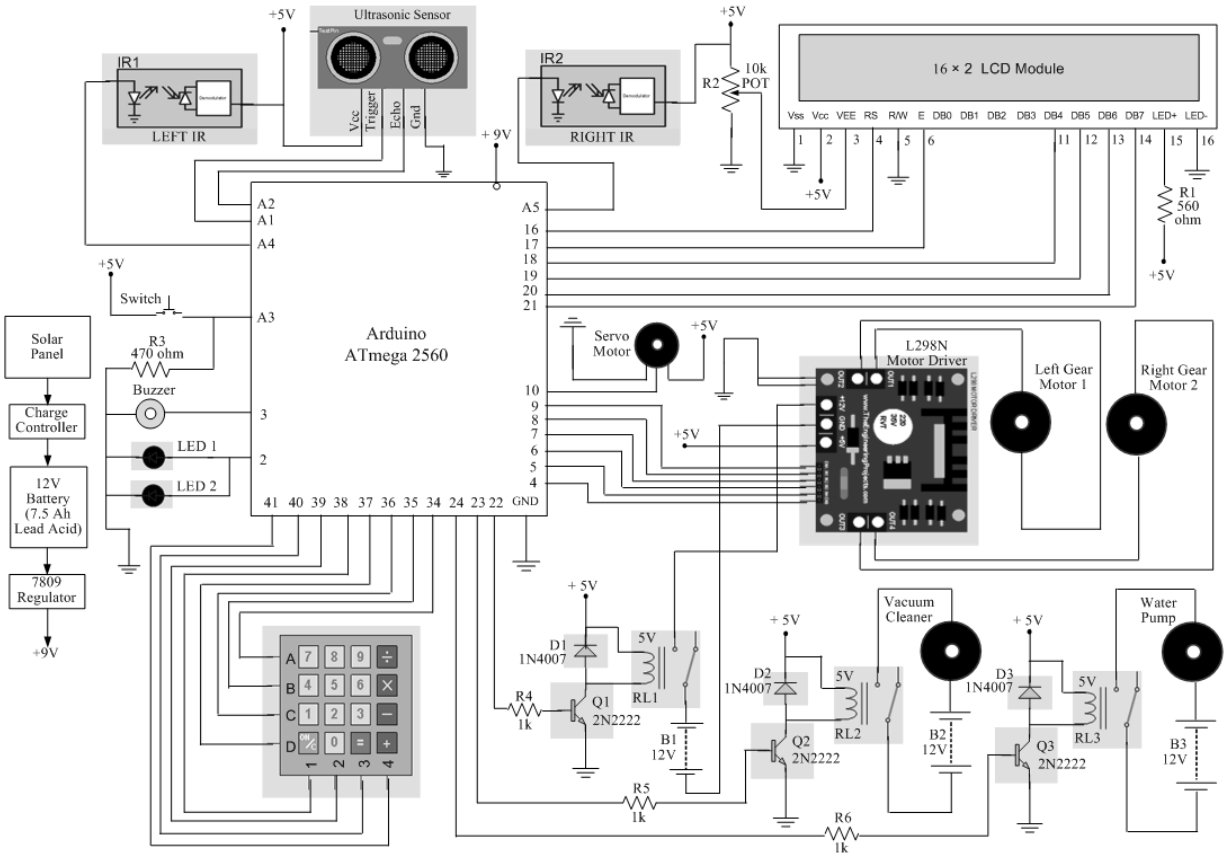

Figure 14. Schematic diagram of Autonomous Robotic Floor Cleaner

enhanced by using the battery monitoring and self-charging system. It can be also incorporated the location detection feature by using the advanced Arduino board like Rasberry Pi and other advanced modules such as GPS module to detect cleaning location and record the information about the cleaning space.

7. Conclusion

This paper presents the design of the floor cleaning robot using Arduino Mega 2560 and motor control design with manual cleaning devices and tools. It is an autonomous system which can control all of its activities by itself. Is is simple and natural human-robot interface and low cost cleaning robot. This cleaning robot can smart enough to detect all objects and edges in any position of the room. Aunomou Roboic Floor Cleaner is used from industries to home and is becoming a very important part of life as it saves time, money and reduce human power. It provides cleaning activities with much more efficiency without human effort.

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