Development of Arduino Programme Code for Autonomous Smart Vacuum Robot

D. C. PATEL,
Associate Professor, Mechanical Department, GIDC Engineering College, Abrama, Gujarat, India

H. S. PATIL
Professor, Mechanical Department, GIDC Engineering College, Abrama, Gujarat, India.

Abstract – Automatic floor cleaner is a system that enables cleaning of the floor with the help of highly stabilized and rapidly functionalized electro- mechanical control system. This paper aimed to develop arduino programme code for autonomous smart vacuum cleaner robot use to clean large floor area of houses or offices. The idea is basically to detect any obstacle with the help of sensor and send its output to a microcontroller that will control the Autonomous vacuum cleaner movement. By using autonomous vacuum cleaner, user can turn ON the Autonomous vacuum robot to clean without any help of human operator. Once this machine is put in ON mode it moves on all over the floor surface to cover whole a floor area. Also it changes its path in random manner with obstacles in the path or sudden step down in floor space. In smart vacuum robot, proper cleaning is achieved with controlled motion of vacuum cleaner and scrubbing action of broom along with vacuum action. The purpose of this paper is design and develop efficient low cost AI vacuum cleaner with the help of Arduino microcontroller's, sensors and motors.

Index Terms – Smart vacuum robot, Arduino microcontroller, sensors.

1. INTRODUCTION

The broom is the most common tool used to clean the floor in houses and offices and cleaning staffs, maids and servants are employed for the 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.

The main aim of this work is to create an artificially intelligent vacuum cleaner that would require negligible human guidance, reduce human time utilized on cleaning purpose and efficient sweep. For time saving, safety and effective cleaning in house and offices, an automatic cleaning system needed that works and cleans on its own without human control/intervention. The idea of leaning with artificial robot is not a new but use of microcontrollers, sensor and motors capability decides the effectiveness of final product. Generally implication on cleaning robot was done by using various techniques such as by using Rasp - berry Pi, Arduino, 8051 microcontroller etc. Every implication was having advantages and limitations. On the basis of limitations study with different microcontroller, Arduino mega 2560 controller used for this purpose. The key highlight of in this project is obstacle avoidance, auto path decision, simultaneous brooming and vacuuming process. Here we are using sensors to detect the obstacles. The cleaning robot uses a microcontroller to detect obstacles and manipulates its direction as per the input from sensors mounted in front; right and left of the robot and the distance will be rerouted automatically.

2. LITERATURE REVIEW

A robotic vacuum cleaner is an autonomous electronic device that is intelligently programmed 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.

2.1 . iRobot[2]

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 increased market 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

2.2. NEATO Robotics [3]

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

2.3. Dyson[4]

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[5]

• 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.)

A comparison of our proposed robot with the top selling robotic cleaners in international market on the basis of general specifications like operating time, charging time, scheduling, floor type, battery indicators and navigation features is studied. A detailed comparison of previous patented robotic vacuum cleaners on the basis of main features of control mechanism like automatic or manual mode and cleaning expertise like dry vacuum cleaning or mopping along with additional features like bag-less container etc. is summarized.

2.4 Patents summary

2.4.1 Autonomous floor mopping apparatus US-6,741,054 [7]

Minor feature: Autonomous and remotely controlled robot, while robot moves, motor system feeds roller towelling and take up roller reels in the towelling.

Major feature: Robot motion is controlled using IR sensor and manually controlled using GUI controls, cleaning via simple roller brushing and vacuuming.

2.4.2 Autonomous floor cleaning robot US-6883201B2 [8]

Minor feature: Cleaning capability and efficiency is optimized through independent vacuum assembly, a removable dust collector, A control system, in communication with the motive system having feedback from sensors.

Major feature: Separate vacuum assembly, Dirt compartment with auto disposal. Autonomous motion using IR sensor mechanism and manually controlled via GUI controls

2.4.3 Autonomous surface cleaning robot for wet and dry cleaning US- 7,389,156 [9]

Minor feature: The robot chassis carries cleaning elements to suck particles up from the cleaning surface and apply a cleaning fluid onto the surface to collect the cleaning fluid up from the surface using a rotating sponge, The robot includes controls and drive elements configured to control the robot using sensor mechanism, A removable dust cartridge with separate tank for cleaning fluid.

Major feature: A roller brush brooming the dirt into dirt compartment aided by a vacuum cleaner, Autonomous motion using IR sensor mechanism and manually controlled via GUI controls, Dirt compartment with auto-disposal.

2.4.4 Cleaning Robot and control method There of US-2013/0231819 [10]

Minor feature: Contains a movement module, a sound wave sensor module, a cleaning module (vacuum only) and a controlling module.

Major feature: Autonomous motion using IR sensor mechanism and manually controlled via GUI controls with brushing and vacuuming.

2.4.5 Autonomous surface cleaning robot for dry cleaning US-8,782,848 [11]

Minor feature: Includes a transport drive and control system arranged for autonomous movement of the robot, Vacuuming

assembly and a waste container for storing waste, Also includes wet cleaning separately.

Major feature: Autonomous motion using IR sensor mechanism and manually controlled via GUI controls, brushing and vacuuming assembly with a waste container capable of auto-disposing, Wet cleaning feature is not available.

2.4.6 System and method for autonomous mopping of a floor surface US-8,892,251 [12]

Minor feature: Cleaning the surface with a cleaning pad and cleaning solvent, Movement of robot can be programed by a class of trajectories that achieve effective cleaning. The trajectories include sequences of repeated steps like forward and backward motion with optional left and right motion in accurate paths.

Major feature: Brushing and vacuuming with auto-disposal of waste, Movement is controlled by IR sensor data using obstacle avoidance technique but can be programmed for calculated trajectories and orientations using a Magnetometer module.

3. DESIGN OF AI VACUUM CLEANER

Mechanical body consists of four parts i.e., chassis, brushing mechanism, vacuum cleaning and dirt disposal mechanism. Combination all these four parts makes a complete prototype for testing, as shown in Figure 1. Before fabrication, complete CAD Model was designed using SOLIDWORKS 3D modelling software.

3.1. Chassis

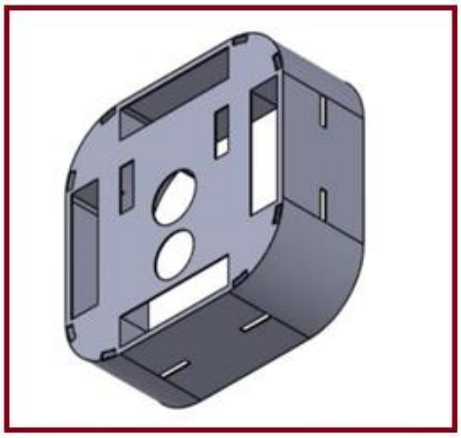

Figure 1: Isometric view of chassis of vacuum cleaner

The base of the body comprises of powder coated MS sheet of 1.5mm thickness, one encoder motors along with Teflon tires having O-rings on them for avoiding friction and another servo motor for direction change, two ball casters of adjustable height having frictionless steel balls, aluminium angular brackets and aluminium holders for two lead acid batteries of 12V and 1.2Ah rating. These motors are independently powered and mounted diagonally and two ball casters are placed at other diagonal of sheet so that motors can move along its axis easily and bear more weight of whole mechanism.

Figure 2: Assembly of vacuum cleaner

Cleaning assembly includes 1800 rpm DC motor to create sufficient vacuum through screen and dust bag to collect dust particles, one DC geared motor is use to rotating brush and four aluminium rods for supporting vacuum cleaner mechanism and dirt compartment. This DC geared motor has been fitted on one side of sheet with aluminium holder and sprockets installed with it which have been fitted into shaft of motor. All components are installed on lower side of sheet so that centre of gravity should be lower and robot would be stable.

3.2. Brushing

Brushing mechanism consists of four rolling brush, aluminium end holders, ball-bearing and Teflon bevel gears mechanism. One rolling brush shaft rotated with DC geared motor and motion is transmitted to other shafts and brushes through bevel gear mechanism. 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.

Figure 3: components for brushing mechanism of vacuum cleaner

3.3. Vacuum Cleaning and Dirt Disposal

Vacuum cleaning and dirt disposal mechanism consists of vacuum motor (1800 rmp), propeller, steel holders for fixing motor into vacuum piping arrangement, filter mounted in the vacuum tunnel and accumulated dust is collected in detachable plastic bag. Propeller mounted to a vacuum motor fixed by steel holders and filters are placed on inside of plastic pipe body.

Both sheet chassis and vacuum tunnel 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. At very last end of vacuum tunnel high speed DC motor installed to dispose the dirt into plastic bag collector. Vacuum Cleaner battery holder is spot welded on inner side to support 18.1V, 5AhLiPo battery.

Figure 4: High speed DC motor, blower fan and dust collector mechanism

3.4 Electronic Circuitry

All circuits are first designed and simulated in Proteus and Arduino software. After optimization of values for Components, circuits were implemented on PCB. There are Arduino mega board circuits including 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 commonly known as H-Bridge, are used for driving motors in both direction that is clockwise and counter clockwise with current rating of 15 A. This controller consists of two parts. First part is to energize relays through Arduino mega 2560 controller and drive motors while second part is for controlling the speed of motors.

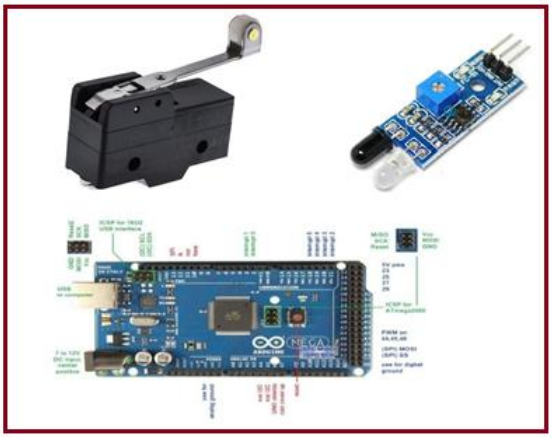

Figure 5: Arduino mega 2560 microcontroller, IR sensor, Limit switch

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 to transistor 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 and a Red LED glowing if the circuit is disconnected owing to section: 4 of IEEE Std. 1621.

B. Vacuum Cleaning Controller

The 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 for supplying power to vacuum cleaner with different ground terminals to avoid short circuit currents and properly isolate the batteries from circuit including a separate Yellow LED for Disconnected state owing to section: 4 of IEEE Std. 1621. Signal from Arduino controller is given to transistor BJT 2N2222 which energizes relay and relay switches. After switching, relay will allow 18V battery to supply power

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.

3.5 Brushing Motor Controller

The circuit consists of two transistors. One transistor takes a signal from Arduino controller and drives other transistor. Transistor which takes a signal is BJT 2N2222 and other one is TIP-122. Circuit works

on 12V DC supply connected through a switch and fuse. Two transistors are used because single TIP- 122 has high current rating and cannot be activated by Arduino directly. Transistor BJT 2N2222 is not used solely because stall current of brush motor is much high and BJT will not provide necessary current. So combination of these two gives a successful circuit to drive brush motor.

3.6 Power Supply to Sensors

All IR and limt switch sensors used are rated at 5V but batteries are of 12V and 18V. So to give 5V to four IR sensors, 2 encoder sensors, 8 limit switch sensor, and this circuit has been designed and implemented. Regulator IC 7805 is used for converting 12V to 5V with current in milliamperes 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 labelled as disconnected owing to section: 3.1.14 of IEEE Standard 1621.

3.7 Precautionary Circuit

This circuit serves as a main 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. Firstly battery terminals are connected to terminal block shorted with inputs of bridge rectifier that is KBPC 5040 having a voltage rating of 1000V and 50A. 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. 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. Regulator used is LM338k which is positive adjustable voltage regulator having a rating of 15A and can regulate voltage from 12V to 6V. This regulator is used so that there will be no fluctuations in output and motor works steadily. After adjusting voltage to 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 used is 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. Further for testing long wires are used for connecting between output terminal blocks of motor battery and circuit battery. Power Switches (section: 3.1.11 of IEEE Std. 1621) are also attached with these wires to turn on or off in any emergency.

4. ARDUINO SOURCE CODE

```
#include <VarSpeedServo.h>
VarSpeedServo myservo;
int ena= 6; //dc motor input
int m1= 7;
int ir1= 30; //infrared sensor inputs
int ir2= 31;
int ir3= 23;
void setup()
{
myservo.attach(9); //servo motor connected with pin 9
pinMode(2,INPUT_PULLUP); //front limit switch
pinMode(3,INPUT_PULLUP); //right limit switch
pinMode(4,INPUT_PULLUP); //left limit switch
pinMode(5,INPUT_PULLUP); //back limit switch
pinMode(ir1,INPUT); //front infrared sensor
pinMode(ir2,INPUT); //right infrared sensor
pinMode(ir3,INPUT); //left infrared sensor
pinMode(ena,OUTPUT);
pinMode(m1,OUTPUT);
Serial.begin(9600); //initialize serial connection at 9600 bits per second
Serial.println("Hello");
myservo.write(0); //initialize servo motor position
myservo.write(90); //turn servo motor by 90 degrees
myservo.stop(); //stop servo motor at 90 degrees
digitalWrite(ena,HIGH); //set dc motor direction
40
analogWrite(m1,50); //set dc motor speed
}
void loop()
{
int ls1= digitalRead(2);
int ls2= digitalRead(3);
int ls3= digitalRead(4);
int ls4= digitalRead(5);
int IR1= digitalRead(ir1);
int IR2= digitalRead(ir2);
int IR3= digitalRead(ir3);
if(ls1==HIGH||ls3==HIGH||IR1==LOW||IR3==LOW)
{
digitalWrite(ena,LOW);
analogWrite(m1,00);
```

```
delay(100);
myservo.write(90,50,true);
for(int i=0;i<=29;i++)
{
delay(100);
digitalWrite(ena,LOW);
analogWrite(m1,225);
delay(150);
}
delay(100);
digitalWrite(ena,HIGH);
analogWrite(m1,0);
delay(50);
myservo.write(90);
for(int i=90;i<=130;i++)
{
41
myservo.write(i,50,true);
delay(100);
digitalWrite(ena,HIGH);
analogWrite(m1,50);
delay(100);
}
myservo.write(90,10,true);
digitalWrite(ena,HIGH);
analogWrite(m1,50);
}
else if(ls2==HIGH||IR2==LOW)
{
digitalWrite(ena,LOW);
analogWrite(m1,00);
delay(100);
myservo.write(90,50,true);
for(int i=0;i<=29;i++)
{
delay(100);
digitalWrite(ena,LOW);
analogWrite(m1,225);
delay(150);
}
delay(100);
digitalWrite(ena,HIGH);
analogWrite(m1,0);
delay(50);
myservo.write(90);
for(int i=90;i>=50;i--)
{
myservo.write(i,50,true);
delay(100);
digitalWrite(ena,HIGH);
analogWrite(m1,50);
42
delay(100);
}
myservo.write(90,10,true);
digitalWrite(ena,HIGH);
analogWrite(m1,50);
}
else
{
myservo.stop();
}
}
```

5. OPERATIONS OF AI VACUUM CLEANER

The proposed AI vacuum cleaner is fully autonomous and manual featured with user friendly interface. The vacuum cleaner is able to clean, brush and auto dispose-off. It has variable speed and power efficient. The testing of the robot showed that it can achieve almost all the functionalities which were planned to implement originally. it can be used in autonomous and manual modes as per user's will. During its autonomous mode, this robot can be scheduled with a proper date and time. When that date/ time comes this product automatically starts and cleans the whole room. The manual mode of AI vacuum cleaner is use to save the energy of the robot and to clean the particular place. Customers are provided with the user friendly interface to operate the robot without any difficulty. Most importantly proposed cleaner consumes extremely low energy which is 90W. This AI Vacuum cleaner has the secondary safety circuit which rectifies different poles and restricts high voltage to affect the circuitry. However, this robot can't do wet cleaning.

6. RESULTS AND CONCLUSIONS

An AI vacuum cleaner is successfully developed at low cost with all the features up to the standards of IEEE. This paper shows the implementation of IEEE Standard 1621 IEEE Standard for User Interface Elements in Power Control of Electronic Devices used in Office/Consumer Environments in terms of smart floor cleaning robot. The work concludes with following points.

1. Arduino Mega 2560 is sufficient to control the required inputs and outputs for smart vacuum cleaner.
2. The Indigenous vacuum tunnel made with 18,000 rpm DC motor is sufficient to vacuum small objects for commercial cleaning purpose.
3. The indigenous wiper system made with Teflon bevel gears is strong enough to wipe the floor.
4. The indigenous Arduino logic programme for working of limit switch, infrared sensor and drive motors is sufficient to turn smart vacuum cleaner in commercial floor by developing arbitrary path and cover all the floor area.
5. The developed AI vacuum cleaner is highly cost effective compared to commercially available smart vacuum cleaners.

Features of this AI vacuum robot can be further enhanced with implementation of distance sensors, GPS sensors and automatic charging system operated with android and windows app.

REFERENCES

[1] IEEE Standard for User Interface Elements in Power Control of Electronic Devices employed in Office/Consumer Environments, IEEE Standard 1621,2004(R2009).
[2] Irobot.com, 'iRobot Corporation: We Are The Robot Company', (2015). [Online]. Available: http://www.irobot.com/.
[3] Neato, 'Neato Robotics | Smartest, Most Powerful, Best Robot Vacuum', (2015). [Online]. Available: http://www.neatorobotics.com/.
[4] Dyson.com, 'Latest Dyson Vacuum Cleaner Technology | Dyson.com', (2015). [Online]. Available: http://www.dyson.com/vacuum-cleaners.aspx.
[5] Dyson 360 Eyeâ„¢ robot, 'Dyson 360 Eyeâ„¢ robot',(2015). [Online]. Available: https://www.dyson360eye.com/.
[6] Buck, 'The Best Robot Vacuums of 2015 | Top Ten Reviews', Top Ten REVIEWS, (2014). [Online]. Available: http://robot-vacuumreview.toptenreviews.com/.
[7] Harvey Koselka, Bret A. Wallach, David Gollaher (2004).,"Autonomous floor mopping apparatus," U.S. Patent 6741054 B2, May 25,2004
[8] Joseph L. Jones, Newton E. Mack, David M. Nugent, Paul E. Sandin, (2005)"Autonomous floor-cleaning robot," U.S. Patent 6883201, B2, April 6, 2005.
[9] Andrew Ziegler, Duane Gilbert, Christopher John Morse, Scott Pratt, Paul Sandin, Nancy Dussault, Andrew Jones,(2008) "Autonomous surface cleaning robot for wet and dry cleaning," U.S. Patent 7389156 B2, June 17, 2008.
[10] Shih-Che HUNG, Yao-Shih Leng, (2013)"Cleaning robot and control method thereof," U.S. Patent 20130231819 A1, September 5, 2013.
[11] Andrew Ziegler, Christopher John Morse, Duane L. Gilbert, Jr., Andrew Jones,(2014) "Autonomous surface cleaning robot for dry cleaning," U.S. Patent 8782848 B2, July 22, 2014.
[12] Michael Dooley, James Philip Case, and Nikolai Romanov,(2014) "System and method for autonomous mopping of a floor surface," U.S. Patent 8 892 251 B1, November 18, 2014.
[13] A. Louchene and N. E. Bouguechal, ,(2003) Indoor mobile robot local path planner with trajectory tracking, Journal of Intelligent and Robotic Systems, Vol. 37 (2003), pp. 163–175.
[14] Hiba Ghannam Hawa' Osama, 2012.
[15] Robotic vacuum cleaner, An-Najah National University, (2012)[15] H. Mori, S. Kotani and N. Kiyohiro, (1999), A robotic travel aid 'HITOMI', Proceedings of the IEEE/RJS/GI, International Conference on Intelligent Robot and Systems, Vol. 13 (1999), pp. 1716–1723.
[16] J. W. Lee, S. U. Choi, C. H. Lee, Y. J. Lee and K. S. Lee, (2001), A study for AGV steering control and identification using vision system, Industrial Electronics, Vol. 3 (2001), pp. 12-16; pp. 1575–1578.
[17] Min-Chie Chiu and Long-Jyi Yeh, (2008)The design and application of a robotic vacuum cleaner, Chungchou Institute of Technology and Tatung University, April 2008.
[18] M. D. Mohsen and M. M. Majid, Stair Climber (2008)Smart Mobile Robot (MSRox), Tarbiat Modares, University of Iran, Iran Autonomous Robots, Vol. 20 (2006), pp. 3–14. Malaysia Melaka, May 2008.
[19] Y. X. Chen, (2002.)Design and Implementation of Car-Like Mobile Robot with Intelligent Parking Capability, Department of Electrical Engineering, NCKU, ROC, 2002.
[20] Y. Ando and S. Yuta, (1995) Following a wall by an autonomous mobile robot with a sonarring, IEEE International Conference on Robotics and Automation, Vol. 4 (1995), pp. 2599–2606.

Authors

D. C. PATEL received a M. Tech. degree and Ph.D. degree in Mechanical Engineering from S.V. N. I. T., Surat (India) respectively. Currently working as Associate Professor, Mechanical Department, GIDC Engineering College, Abrama, Gujarat, India Navsari, affiliated with Gujarat Technological University Ahmedabad, Gujarat, India. His research interests include are Design and Manufacturing, Atuomation, and so on.

Dr. H. S. Patil received a M. E. degree and Ph.D. degree in Mechanical Engineering from S.V. Regional Engineering College and Veer Narmad South Gujarat University, Surat (India) respectively. Currently working Professor and Head in Mechanical Department, GIDC Degree Engineering College, Abrama, Navsari, affiliated with Gujarat Technological University Ahmedabad, Gujarat, India. His research interests include are Design and Manufacturing, Materials Characterization and Weld Joint design by FSW and so on.