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Designing a Smart Vacuum Cleaner in Two Modes of Remote and Automatic

Amir Talebi Sheikh Sarmast[1], Tahere pourseif[1], Rozhina Esmaeil Nezhad[2], Mina Mohajeri[1], Saman Mohammadi[3], Aida Vaezi[2]

[1]Department of Electrical engineering, Shahid Beheshti University, Tehran, Iran
[2]Department of Electronic and Robotic, Masoumeh Institute, Tehran, Iran
[3]Saman Mohammadi, Principal of Labobin Muhendislik Company, Istanbul, Turkey country

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Abstract - *In this study, we designed and developed a vacuum cleaner in two modes of remote (through which the vacuum cleaner is controlled by an Android smart phone) and automatic control. Under such mechanism, damage to the vacuum cleaner's battery can be avoided by measuring the battery voltage level and sending an SMS to the user. It also sends a message to the user's phone when the cleaning is done. This paper is the first study to develop a vacuum cleaner in two modes of remote and automatic. Optimal energy consumption and permanent ignition of the suction motor which increase the life of the suction motor are among the main advantages of a vacuum cleaner controlled remotely.*

Key Words: Rotary encoder, pro mini Arduino, Smart vacuum, Sim800L module, HC06 Bluetooth module, android application

1. INTRODUCTION

In today's world, the use of vacuum cleaners for cleaning purposes has become widespread and inevitable. Enhancement of cleanliness, ease of use, and quality as the main features of vacuum cleaners make them a must have in every home. On the other hand, the development of the vacuum cleaner manufacturing industry and the provision of advanced product specifications which facilitate customer use and increase its efficiency require further understanding of the industry as well as the product [1].

The first vacuum cleaner was invented in 1860. The broom consisted of rotating brushes which provided the driving force for the brushes to rotate on rollers on the ground. A continuous flow of air with suction was also created by moving an accordion aperture from one side [2]. The first patented vacuum cleaner known as the "carpet cleaner and electric dust collector" was introduced in Georgia in December 1900. The first electric vacuum cleaner in Europe dates back to 1910. The device weighed 17.5 kg and was powered by One person was used alone [3].

In 1907, a vacuum cleaner which consisted of a fan, box and bag was invented. In addition to suction, it had a spinning brush to collect trash. Due to the lack of funds to manufacture the product, the inventor sold the technical knowledge to Hoover [2].
1979 marks the year in which the first vacuum cleaner was produced in Iran. That year, a domestic manufacturer licensed by Electrolux Sweden produced 26,800 vacuum cleaners. Since then, the production of vacuum cleaners grew steadily, reaching to 7,000,99 in 1985. In 1982, there was no domestic production in Iran. Also, with the currency problems caused by the imposed war, the production of vacuum cleaners declined dramatically between 1986 and 1989. The second domestic manufacturer to set up a vacuum cleaner production line started manufacturing vacuum cleaners under the AEG license in 1988. Another domestic manufacturer which started producing vacuum cleaners in 1992 and is currently operating under the Electrolux license, produces vacuum cleaners of 1200 watts with a nominal capacity of 120,000 units per year. Currently some major manufacturers as well as some small manufacturing businesses are working to produce this product domestically, with a total nominal capacity of 780,000 units per year.

Today, creating networks of smart devices is trending. Ranging from energy and power production systems such as with renewable sources, energy storage [4-6], and their advanced control [7], down to local power utilities and consumer electronics devices, smart control in lieu of conventional and sub-optimal operation is being integrated into this network of devices. The smart control at consumer level translates into subsequent ease of operation, automation, quality and leisure. Currently, vacuum cleaner manufacturers are interested in designing low power, small, light, less noisy and efficient vacuum cleaners with powerful suction. The automated vacuum control technology is applied to the new generation of vacuum cleaners. In this technology, the vacuum cleaner cleans the place at the scheduled time and returns to its charging base after cleaning. This technology is very useful for those who are outdoors and do not have much time for cleaning. Companies and public places such as restaurants and hotels may also find this method efficient and useful [8-10].

This paper focuses on the design of a vacuum cleaner in both automatic and remote control modes. In the remote control mode, the vacuum cleaner can be controlled using your

Android smartphone. By cleaning the vacuum cleaner, controlling the motors, and adjusting their speed with a smart phone, any place may be cleaned. In this case, the user is notified of the battery's low voltage level through an SMS while preventing him/her from sweeping to the position of the shaker by sweeping away. The main advantages of this system lie in extended battery life (due to sending a low battery alert to the user), low power consumption (due to the function of the vacuum cleaner in the remote control mode), and the inefficiency of the suction motor in clean areas. In addition, controlling the suction motor's idle time and brightness in both modes extends the life of the suction motor as an important part of a vacuum cleaner while reducing cost and energy consumption. In addition to its simplicity and convenience, using the mobile phone as a professional remote control reduces the costs associated with using a robot. In the automatic mode, the user schedules the sweeping time through texting the time.

The structure of this article is self-explanatory. This paper deals with the design of a dual-purpose vacuum cleaner in the second section. The main components of the system are introduced and explained in the third section, followed by elaborating the simulation, main circuit, overall structure, and the result. The article concludes with the optimal performance of the designed system.

2. THE DESIGN OF A SMART VACUUM CLEANER

As discussed in the previous section, this article centers on the design of a dual-purpose vacuum cleaner as follows:

Remote control: In this mode, the vacuum cleaner is paired with the mobile phone via Bluetooth. Depending on the application installed on the mobile phone, the drive motors of the system are controlled to move to different parts of the desired location. The suction motor is also controlled for cleaning. Furthermore, by adjusting the speed of the motors, the user can move the robot to the desired location at the desired speed. In this mode, after measuring the voltage level of the battery, the user is notified of the battery voltage and its low level. Therefore, the user directs the vacuum cleaner to the charging base, preventing it from turning off suddenly. This mode is very suitable for situations where only some parts of a location need cleaning. This mode also prevents the robot from sweeping clean places.

Automatic control: In this mode, the user automatically controls the robot's cleaning time after pairing it with the cell phone via Bluetooth. The robot starts cleaning at the scheduled time with the algorithm designed on it and sweeps all parts of the desired location. The completion of the task is announced to the user through a text message. The robot eventually moves to the charging base for recharge. This mode is very useful in situations which the user is outside the home. The following figure shows the designed vacuum cleaner block diagram.

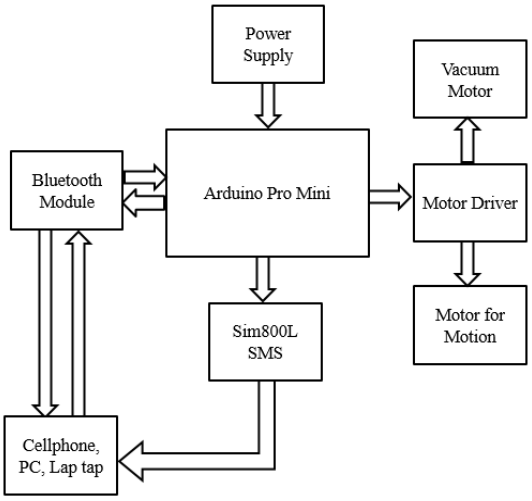

Fig. 1. Smart vacuum cleaner block diagram

As it can be seen, in the automatic mode, a character is sent from the mobile phone to the Arduino board via Bluetooth. Upon receipt of the character, the vacuum cleaner's cleaning time is sent to our handset. The vacuum cleaner starts at the scheduled time and the user is notified through a text message when the task is completed. In the remote control mode, the robot can be controlled from a mobile phone and directed to any place of users' choice. In this case, both the direction and speed of the motors can be controlled simultaneously. The vacuum suction motor is also switched on and off. The battery voltage level is automatically measured, and once it reaches one-third of the full voltage level, a message is sent to the user indicating the need to recharge the battery.

3. MAIN COMPONENTS OF THE SMART VACUUM CLEANER

This section introduces the electric components of the robot.

3.1. Arduino Pro Mini

The Arduino Pro Mini is a microcontroller board based on the ATmega328p. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 8 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six-pin header can be connected to an FTDI cable or Sparkfun breakout board to provide USB power and communication to the board. Schematic the pro mini board is shown in figure 2 [11].

Fig. 2. Pro Mini Board [12]

The Arduino Pro Mini is intended for semi-permanent installation in objects or exhibitions. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. The pin layout is compatible with the Arduino Mini. There are two versions of the Pro Mini. One runs at 3.3V and 8 MHz, the other at 5V and 16 MHz. The Arduino Pro Mini was designed and manufactured by SparkFun Electronics. The summary of pro mini is shown in table 1 [13].

Table. 1. Summary of Pro Mini

Microcontroller	Atmega 328p
Operating Voltage	$3.3\ v - 5\ v$
Input Voltage	$3.3 - 12\ v$
Digital I/O Pins	14
Analog Input Pins	8
PWM Input Pins	6
Flash Memory	$32\ KB$
SRAM	$2\ KB$
EEPROM	$1\ KB$
Operating Frequency	$16\ MHZ$

Pin 0 is (RX) and pin 1 is (TX) used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the TX-0 and RX-1 pins of the six-pin header.

3.2. Motor Driver

This dual bidirectional motor driver is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow you to easily and independently control two motors of up to 2A each in both directions. It is ideal for robotic applications and well-suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board is equipped with power LED indicators, on-board +5V regulator and protection diodes. Motor driver is shown in figure 3 [14].

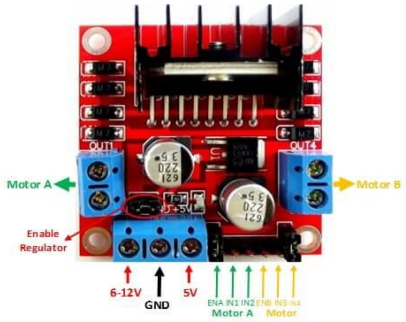

Fig. 3. Motor Driver Arduino

The motor driver's brief data is shown in table 2.

Table. 2. brief data of motor driver

Input Voltage	$3.2\ v - 40\ v$
Power supply	$5\ v - 35\ v$
Peak Current	$2\ Amp$
Operating Current range	$0{\sim}36\ Amp$
Enable Signal Input Voltage range	$0.3v - 1.5v\ control\ signal\ is\ invalid$ $2.3v - vss\ control\ signal\ active$

3.3. HC-06 Bluetooth Module

The Bluetooth module will act as an interface between smartphone and microcontroller. We will be using HC-06 Bluetooth module for the system, either as a receiver or transmitter. Generally, our transmitter will be smartphone and the receiver will be Bluetooth module. The Bluetooth module will give the commands given by smartphone to the microcontroller [15]. The Bluetooth module is shown in figure 4.

Fig. 4. HC-06 Bluetooth Module

The properties of HC-06 Bluetooth module are shown in table 3[16].

Table. 3. Properties of HC-06 Bluetooth Module

Operating Voltage	$3.3\ v$
Current	$5\ mA$
Operating Frequency	$2.4\ MHZ$
Rang	$10-23\ m$
Range of Operating temperature	$25-75°C$
Speed Max	2.1 Mbps
Protocol communication	USART Serial

3.4. Sim800L Module

You can use this module to accomplish almost anything a normal cell phone can; send text messages, make or receive phone calls, connect to internet through GPRS, TCP/IP, and more! To top it off, the module supports quad-band GSM/GPRS network, meaning it works pretty much anywhere in the world. At the heart of the module is a SIM800L GSM cellular chip from SimCom. The operating voltage of the chip is from 3.4V to 4.4V, which makes it an ideal candidate for direct LiPo battery supply. One side of Sim800L module is shown in figure 5 [17].

Fig. 5. Sim800L Module

All the necessary data pins of SIM800L GSM chip are broken out to a 0.1″ pitch headers. This includes pins required for communication with a microcontroller over UART. The module supports baud rate from 1200bps to 115200bps with Auto-Baud detection. The module needs an external antenna to connect to a network. The module usually comes with a Helical Antenna and solders directly to NET pin on PCB. The other side of Sim800L module is shown in figure 6 [18].

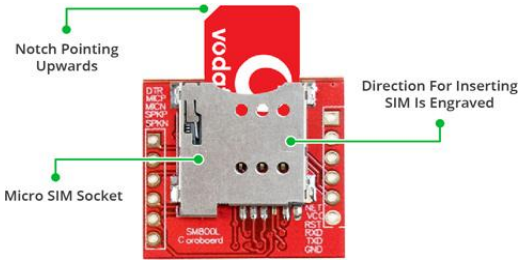

Fig. 6. Other side of Sim800L Module

There's a SIM socket on the back! Any activated, 2G micro SIM card would work perfectly. Correct direction for inserting SIM card is normally engraved on the surface of the SIM socket. This module measures only 1 inch^2 but packs a surprising amount of features into its little frame.

3.5. LM2596 Module DC/DC Converter

LM2596 DC to DC step down regulator, adjustable +1.23 to 35vdc output, 2A. Ideal for battery operated projects requiring a regulated power supply. The specifications of LM2596 are shown in table 4[19].

Table. 4. Properties of HC-05 Bluetooth Module

Regulator Type:	Step Down (Non-Isolated input to Output)
Input Voltage:	+4 to 40vdc
Output Voltage:	+1.25 to 35vdc
Output Current:	2A Rated, (3A maximum with heat sink)
Switching Frequency:	150kHz
Efficiency:	Up to 92% (when output voltage is set high)
Dropout Voltage:	2vdc minimum
Load Regulation:	+/- 0.5%
Voltage Regulation:	+/- 2.5%
Temperature:	-40 to +85 deg C (output power less than 10 Watts)

The LM2596 module is shown below:

Fig. 7. LM2596 Module DC/DC Converter

3.6. Rotary Encoder Module

The rotary encoder is the modern digital equivalent of the potentiometer. It is used in a wide range of applications because of its robustness as well as unlimited rotation count. The encoder has a disk with evenly spaced contact zones that are connected to the common pin C and two other separate contact pins A and B, as illustrated below in figure 8 [20].

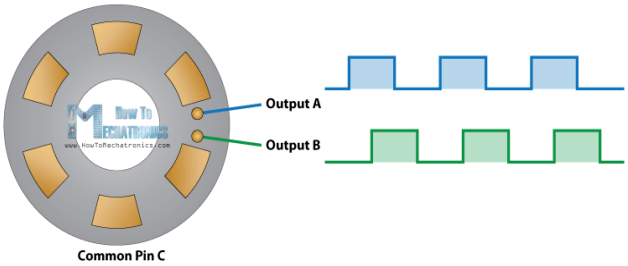

Fig. 8. Rotary mention

When the disk starts rotating step by step, the pins A and B will start making contact with the common pin and the two square wave output signals will be generated accordingly. Any of the two outputs can be used for determining the rotated position if we just count the pulses of the signal. However, if we want to determine the rotation direction as well, we would need to consider both signals at the same time. We can notice that the two output signals are displaced at 90 degrees out of phase from each other. If the encoder is rotating clockwise, the output A will be ahead of output B. The other side of Sim800L module is shown in figure 9.

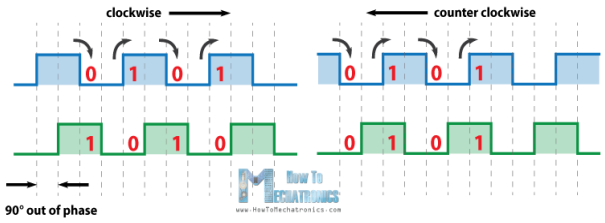

Fig. 9. Rotary angle

So if we count the steps each time the signal changes, from high to low or from low to high, we will notice at that time that the two output signals have opposite values. Vice versa, if the encoder is rotating counter clockwise, the output signals will have equal values. So considering this, we can easily program our controller to read the encoder position and the rotation direction. The rotary encoder module is shown in figure 10 [21].

Fig. 10. Rotary encoder Module

3.7. Software

In both automatic and remote control modes, the robot is paired with electronic devices including but not limited to a mobile phone and laptop via Bluetooth which requires programming. As mentioned in the introductory section, the mobile phone has been used for controlling the robot. Cost efficiency, simplicity, and versatility which suit the user's needs are the main advantages of the control panel. Turning a mobile phone into a control panel requires having an application which is capable of controlling the robot's motors and adjusting its speed simultaneously. Figure 11 shows the designed application.

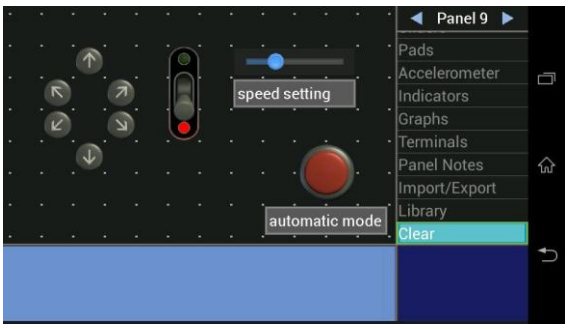

Fig. 11. Robot motors control application on a smartphone

As it can be seen, this application is programmed to control the connection between the mobile phone and the arduino software program, the robot's motors, and their speed. Under such program, the robot goes to the desired location and performs cleaning upon reaching the engine suction location. Therefore, the suction motor is not constantly switched on and its duration and power can be controlled by the above program. It is also used to set the clock to auto mode through text message.

4. SIMULATION AND RESULTS

As explained in the introduction of the main components of intelligent vacuum cleaner design in the previous section, this section deals with simulation and overall structure.

4.1. Smart Vacuum cleaner Simulation

The basic design of the robot in Proteus software is as follows:

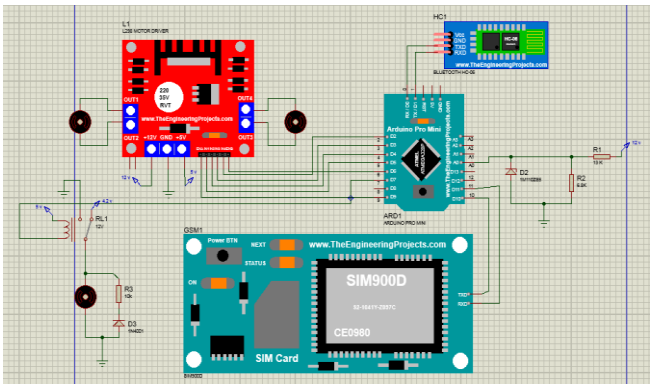

Fig. 12. Design of a vacuum cleaner circuit in Proteus

As shown in Figure 12, the Bluetooth module is cross-linked to the arduino board of the Pro Mini to receive and send data in a serial protocol. The mobile phone connects to the

vacuum cleaner via Bluetooth to control the vacuum cleaner. The L298 module is connected to the motors from the output side and to the arduino board from the input side to supply DC motors. The suction motor has a very high instantaneous current to drive. Therefore, a 10 amp relay module is used to supply the required instantaneous current. This relay is connected to the arduino board on the one hand and to the suction motor on the other hand. The total operating voltage of the system is 5V, which supplies the 1229V, L298 module for the motors, and the voltage and current relay module for the suction motor. The Sim800L and LM2596 modules are respectively used for texting and providing constant working voltage. Since the GSM module is very sensitive to noise, there is a capacitor for noise output at its output. In the automated vacuum cleaner section, the Arduino board is provided with the mobile phone's starting time via Bluetooth communication. The encoder was also integrated into the Arduino board for angle detection, speed adjustment and rotation with 220 ohm resistors and 100 nano capacitors to prevent noise due to the high accuracy of this module. After designing the system, the program is written in the Arduino programming environment as shown in Figure 13.

```
File Edit Sketch Tools Help
final_vacuum
//############ Smart Vacuum program by MINA & TAHERE ###############
#include <SoftwareSerial.h>
SoftwareSerial sim8001(10, 11); // RX, TX
int voltage=A0;
int Motor1A = 2;
int Motor2A = 3;
int Motor1B = 4;
int Motor2B = 5;
int Vacuum_Motor = 7;
int inable_A=6;
int inable_B=9;
int Red_value=0;
int Speed_value=0;
//#########################################################################
void setup()
{
 pinMode(voltage,INPUT);
 pinMode( Motor1A, OUTPUT );
Done Saving
" --change-section-lma .eeprom=0  "C:\Users\irapple\AppData\Local\Temp\arduino_build_627926/final_vacuum.ino
/final_vacuum.ino.elf" "C:\Users\irapple\AppData\Local\Temp\arduino_build_627926/final_vacuum.ino.hex"
```

Fig. 13. Smart vacuum cleaner application in Arduino

4.2. Overall Structure and Results

After designing and programming, the main circuit of the robot vacuum cleaner is as follows:

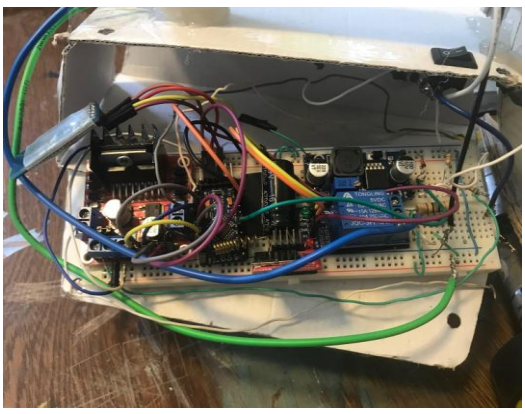

Fig. 14. The main vacuum cleaner circuit

As it can be seen in the figure above, the circuit designed in Proteus software is plugged into the board with all the power supplies needed. The overall structure of the smart vacuum cleaner is as follows:

Fig. 15. The overall structure of the smart vacuum cleaner

As shown in figure 15, the main structure of the smart vacuum cleaner is upward. Lithium-ion batteries are used to supply the entire voltage of the robot. A 5V battery with a 5V capacity is used to supply instantaneous motors and a 2.5V 5V battery has been used in the design of a very high instantaneous suction motor. The current of each battery is multiplied by its capacity which shows the instantaneous flow rate. These batteries are used to keep the engines working. The vacuum cleaner connects to the robot via the Bluetooth in the remote control mode. By turning on the system's power buttons, the system is ready to move. The software installed on the mobile phone controls the motors of the robot and their speed. Finally, the suction motor is turned on and starts vacuuming the place which needs cleaning. Turning on the suction motor not always results in the reduction of energy consumption, the suction motor's life extension, and noise reduction. This process continues until the battery voltage level is not lower than one third. However, when the battery is in discharge mode, an SMS is sent to the user, notifying him/her of the low battery voltage level and warning him/her of a sudden shutdown. Figure 18 shows the text message sent to the user:

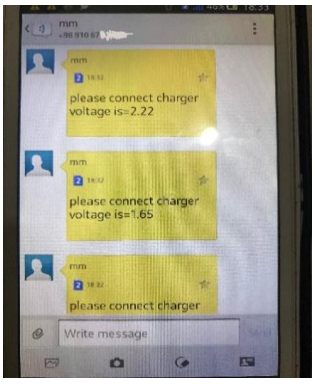

Fig. 16. SMS sent to the user regarding battery voltage level

This will ensure increased battery life.

In auto mode, the auto mode button is turned on and thus, a character is sent to the system via Bluetooth communication. Depending on the programming type, the character receives the query, the start time of the robot is sent to the handset and the user can enter the desired cleaning time. The system switches to automatic setting and will start at the scheduled time. The robot scrolls and sweeps all paths with the algorithm designed on it. That is, any path that counts once and does not pass again unless there is an obstacle in its path. The disadvantage of the automatic mode over the remote control mode is increased power consumption as the suction motor is constantly turned on and cleans the same areas due to obstruction. In this mode, a message will be sent to the user after the task is completed or the vacuum cleaner needs to be recharged. Auto mode is great for users who are not home.

5. CONCLUSIONS

The world of technology nowadays is moving towards automating the most widely used devices. Home appliances including vacuum cleaners are among the things that are moving in this direction. In this article, we transformed a cordless vacuum cleaner into a smart vacuum cleaner. In the remote control mode, the mobile phone is used as a control panel. This reduces power consumption and cost, and extends the life of the suction motor as it is not constantly on. Also, the user is notified of the low percentage of the battery through a message and is being asked to recharge the battery. If the user does not have access to the charging base, the system will automatically shut down after a while, which would in turn prevent damage to the battery. In the automatic mode, the mobile phone is connected to the vacuum cleaner by sending a text message to the vacuum cleaner and the system starts at the designated time. In this study, using a mobile phone in both cases has reduced the costs as well as increased convenience for users.

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REFERENCES

[1] N. Mitchel, The Lazy Person's Guide to a Happy Home: Tips or People Who (Really) Hate Cleaning, 9 Jan 2016 [Online]. Available: http://www.apartmenttherapy.com/the-lazy-personsguide-to-a-happy-home-cleaning-tips-for-people-who-reallyhate- cleaning-197266 [Accessed 22 June 2016].

[2] R. Neato, ''Company Neato Robotics," Neato Robotics, 2015, [Online]. Available: http://www.neatorobotics.com/company/ [Accessed 26 05 2015].

[3] C.o. iRobot, "iRobot:Our History," 29 May 2015. [Online]. Available: http://www.irobot.com/About-iRobot/Company- Information/History.aspx.

[4] M. M. Bijaieh, W. W. Weaver, and R. D. Robinett, "Effects of dq droop settings on energy storage systems of inverter-based microgrids," in 2018 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), pp. 75–80, June 2018.

[5] M. M. Bijaieh, W. W. Weaver and R. D. Robinett III, "Energy Storage Requirements for Inverter-Based Microgrids Under Droop Control in d-q Coordinates," in IEEE Transactions on Energy Conversion, vol. 35, no. 2, pp. 611-620, June 2020, doi: 10.1109/TEC.2019.2959189.

[6] M. M. Bijaieh, W. W. Weaver, and R. D. Robinett, "Energy storage power and energy sizing and specification using hsspfc," Electronics, vol. 9, no. 4, 2020.

[7] W. W. Weaver, M. M. Bijaieh, R. D. Robinett and D. G. Wilson, "Energy Storage Baseline Requirements for Pulsed Power Loads," 2019 IEEE Electric Ship Technologies Symposium (ESTS), Washington, DC, USA, 2019, pp. 52-59, doi: 10.1109/ESTS.2019.8847798.

[8] R.R. Murphy, Introduction to AI Robotics, Massachussetts: The MIT Press Cambridge, 2000, pp. Introduction to AI Robotics - Page 450 - Google Books Result.

[9] Humayun Rashid, Akash Mahmood, S.M. Sarjahan Shekha, Taslim Reza, Md Rasheduzzaman, Design and development of a DTMF controlled room cleaner robot with two path-following method, in: 2016 19th International Conference on Computer and Information Technology (ICCIT), IEEE, pp. 484– 489, 2016.

[10] Erwin Prassler, Mario E. Munich, Paolo Pirjanian, Kazuhiro Kosuge, Domestic robotics, in: Springer Handbook of Robotics, Springer International Publishing, 2016, pp. 1729–1758.

[11] C. Fui Liew, D. DeLatte, N. Takeishi and T. Yairi, "Recent Developments in Aerial Robotics: A Survey and Prototypes Overview", arXiv: 1711.10085v2, 30 Nov 2017.

[12] Z. T. Dydek, A. M. Annaswamy and E. Lavretsky," Adaptive Control of Quadrotor UAVs: A Design Trade Study with Flight Evaluations", IEEE Transactions on Control Systems Thechnology, Vol. 21, No. 4, pp. 1400-1406, 2013.

[13] S. Bhattacharya, H. Rai, "An Asset Finder Using Arduino Pro Mini", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 6, Issue. 2, pp. 850-858, Feb 2018.

[14] M. M. Maung., M. M. Latt., and Ch. M. Nwe, "DC Motor Angular Position Control using PID Controller with Friction Compensation", International Journal of Scientific and Research Publications, Vol. 8, Issue. 11, pp. 149-155, Nov. 2018.

[15] P. V. Gaikwad, Y. R. Kalshetty, "Bluetooth Based Smart Automation System Using Android", International Journal of Science and Research, Vol. 6, Issue. 5, pp. 1003-1006, May 2017.

[16] T. Pourseif, M. Mohajeri, M. Kojouri, S. Rana Hosseini, D. Moaleji, P. Mabhout, and N. Jahan "Designing a Smart Balloon and Android-based Remote Control", International Journal of Scientific Research in Mechanical and Materials Engineering, Vol. 3, Issue. 4, pp. 01-09, Agu 2019.

[17] D. N. Amadi, and J. Triono, "Smart Home Development for Home Security with Android Based", International Journal of Advanced Research in Computer Science, Vol. 8, No. 9, pp. 320-323, Dec 2017.

[18] M. D. Artawan, A. A. N. Gunawan, and M. Sumadiyasav, "Use of Short Message Service (SMS) Based ATmega328 Microcontroller and SIM800L Modules as on / off Control Electronic Equipments", Advances in Applied Physics, Vol. 6, No. 1, pp. 19 – 24, 2018.

[19] M. Kumar, and D. Lama, "Design and Development of Cost Effective automatic cutoff PV Charge Controller with indicator", IOSR Journal of Electrical and Electronics Engineering, IOSR Journal of Electrical and Electronics Engineering, Vol 10, Issue 3, PP. 18-22, Jun 2015.

[20] D. Zheng, and Sh. Zhang, Sh. Wang, Ch. Hu, and X. Zhao, "A Capacitive Rotary Encoder Based on Quadrature Modulation and Demodulation", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, Vol. 64, Issue. 1, pp. 143-153, Jan 2015.

[21] Yi. Ch. Chen, Chi. H. Lee, M. J. Chou, and Sh. Ch. Shen, "High-Precision Digital Rotary Encoder Based on Dot-Matrix Gratings", IEEE Photonics Journal, Vol. 10, Issue. 2, April 2018.