Smart Solar Powered Vacuum Cleaner

ABSTRACT

Cleaning is very important to protect the human health. With the help of a Smart Vacuum Cleaner, the cleaning of the surroundings in a daily basis. In this paper, proposed an efficient way to design and implement a solar energy based smart vacuum cleaner circuit with a Bluetooth module, using Arduino microcontroller. The two sensors Light Dependent Resistor (LDR) sensor and Ultrasonic sensor at the input side, send input data to the Arduino microcontroller. It processes the data and controls the movement of the vacuum cleaner. In addition, this device has an automatic recharging unit along with battery. Once it is done with the cleaning process or at any time if the battery charge goes below threshold, the device will automatically recharge by using solar panel. LDR senses the intensity of sunlight, and the DC motor rotation moves the device to a light source to recharge the solar panel. After completing the cleaning process, the user receives notification to the registered mobile phone via Bluetooth. Th advantage of the device is the cleaning process is done in quickly compared to a manual cabled vacuum cleaner. It is portable, flexible, time saving and power efficient. Its applications are not limited to house cleaning, but also are very useful in food industries, barber shops, in parks to collect falling leaves or any surface that the DC motor can move on,

Keywords:
Smart vacuum cleaner, Light Dependent Resistor, Bluetooth, DC Motor, Arduino, Solar Panel.

Introduction:

Cleaning is an essential process to protect environment and our health. When our surrounding is not cleaned, germs can be generated and may lead to several types of diseases. Few dirt can cause considerable respiratory issues for people, especially those infected with chronic diseases and weak immunity. Hence it is very much vital to keep our surroundings clean and vacuumed (Forlizzi 2007). Currently many devices for cleaning and sanitizing purposes are available in shops which use diesel engines, electric Motors robots etc. Most of the available devices currently used for cleaning of the floors and roads, causes pollution to the environment. Few of them are heavy to carry and requires time for maintenance. For the daily cleaning purpose, when we use a vacuum cleaner, the device should be ecofriendly. For this purpose, a solar based smart vacuum cleaner finds its application, to clean the surrounding surfaces according to user's choice. We can fix a pre-determined pattern or direction of movement to do the cleaning work.
The device will help to remove dust, hackles and dirt accumulating, so that infection from bacteria, allergen or other microbes could be removed up to certain extent from the places that we live in. Complete vacuuming is the effective method to remove complete dirt.
The prototype developed by the proposed technology assist the vacuuming purposes in an efficient manner. The device is more user friendly and with ease of vacuuming even for physically disabled people, with the automatic feature. By using ultrasonic sensor, could be able to do border analysis, by measuring the distance from obstacles or to avoid the block by changing the direction. This device can work with solar energy, the renewable energy (Afarulrazi et al. 2011). By using solar energy, the main advantage is long-term use and energy efficiency. The concept of smart vacuum cleaner using solar energy for the cleaning purpose and notifying the user about the completion of the work.Since the device is using power for the sunlight it is environment friendly as it is the clean green source of energy (Thomas et al. 2018).
In addition to the solar power unit, device is also supported by the battery. The solar panel use sunlight to generate the direct current. The solar panel can operate with different voltage and current levels. There is no negative impact for the system as it collects the clean renewable energy in the form of sunlight then convert it into electricity. It is comprised of several individual solar cells composed of layers of phosphorous, silicon and boron. When thinking about the long term use, solar panel system is power saving and energy efficient (Hoekstra et al. 1996).

Related Work:

The research paper (Hongsik et al. 2019) discuss about the cordless vacuum cleaner with an inverter driven by a single phase brushless direct current (BLDC) motor. In order to meet opening and constant torque, air gap in the single-phase brushless direct current motor is designed asymmetrically by taking into account of voltage fluctuation in the battery.

Here the sufficient output power is maintained by changing the advance and conduction angles in response to the variation of battery voltages. Here the motor efficiency is quite good with the estimated efficiency. But the air flow efficiency could be improved for obtaining high system efficiency. So, if we go for an optimum design, by considering the motor core and the housing structure, the system efficiency will improve

The paper (Stefan 2018) presented a 3D virtual model for the robotic vacuum cleaner. This article is focused on the design of subassemblies which are specif to the vacuum cleaner and illustrates the features by adding new modules to a robotic vacuum cleaner.

This paper presents the 3D virtual model of the robotic vacuum cleaner in terms of vacuum cleaner elements. The paper is focused on the design of the subassemblies specific to the vacuum cleaner and presents the features added by attaching new modules to a robotic vacuum cleaner. Also the paper develops aspects concerning HEPA [High-efficiency Particulate Air] filters how important they are in people's modules and aspects regarding acoustic sensors illustrating how the robotic vacuum cleaner moves in the room for cleaning and also how it avoids obstacles which are in front of it. The main idea of the work is the robotic vacuum cleaner is to fulfil do some work starting with removing all the dust in the floor, then use the clean water to sweep the floor and dry the water after cleaning after that the robotic clean the air by sparing some good smells as possible. The used component are high airflow and ventilators 120mm, but the main limitation of the implemented model in the suction of power. The fan that is used is too small to cover area that is larger than 20m-2 m for that reason the module is used in small area and it cloud be not used in such as public areas or industries.

The article (Tun 2019) discusses about the development of the vacuum cleaner with compact size and lightweight. The main source of power is the battery. The axial flow of fan is responsible for the production of suction pressure. The electric motor that converts the electrical energy into mechanical energy, The filter inside the vacuum stores the particles of the dirt until it is discarded by the user, The disadvantage of the model is the lack of precision in blade design can make the project equipment lower efficiency.

The development of smart vacuum floor cleaning robot used in industrial and domestic purpose for cleaning the floor periodically without need of human intervention (PATE 2017). The implemented model has achieved the implementation of the IEEE Standard User Interface Elements in the control of the power, used for electronic devices in Office, Consumer Environments based on the smart floor-cleaning robot, and the result showed that Arduino Mega 2560 is sufficient to control the required output and input for the vacuum cleaner.

The paper (Balamurugan et al. 2018) discusses about the floor cleaner, works via Bluetooth used for controlling the whole system, with the help of remote or mobile module. It includes the DC motors wired in a wheeled plastic container and a cleaning solution placed on top and a scrub attached in the bottom through one of the motors with the brush that can dry the floor with aid of CPU fan after cleaning the floor. The device is developed operational that gives desired motion. This was first tested in a room within the small area and resulted an effective outcome. The main disadvantage is the motor is not detachable; it can lead to some vibration of entire system as well as the device movement in the direction of dust (Sukumaran 2019). Table 1 provides the summary of discussed articles.

Table 1. Summary of Literatures

Title, author, and year	**Concepts, approach, methods, analysis adopted**	**Inconsistencies and gaps**	**Improvements**
Design of a Single-Phase BLDC Motor for a Cordless Vacuum Cleaner Considering the Efficiency of Airflow, Hwang Hongsik and Cho Jeonghyun and Hwang, Seon-Hwan,2019	Adopted approach is CFD analysis followed by the air flow measurement	The BLDC motor used the electrical commutating mechanism rather than sequence of mechanical commutators and the brushes of the universal motor	Air flow structure focusing in the efficiency through the optimum design by taking care of the housing structure and motor core.
Virtual Model of a Robotic Vacuum Cleaner RADU Stefan,2018	Designing a virtual model of a 3D robotic vacuum cleaner, by using solid works application.	Size of the suction power of the vacuum cleaner is small that cannot cover large spaces.	The features of high-efficiency air filter

Design and Fabrication of Mini DC Vacuum Cleaner, Tun,n. (2019)	A DC controlled vacuum cleaner using axial flow fan that is efficient to generating a suction pressure of (0.17- bar) and eco-friendly.	Axial flow fan which has a precise angle to optimize the amount of air it can displace.	Centrifugal fans are more useful in extract air at right angles and spin the air outwards to the store by deflection and force of centrifugal.
Development of Arduino Program Code For Autonomous Smart Vacuum Robot , D. C. PATEL and Dr. H. S. Patil,2017	Developing the cleaning device facilitate effective by using Arduino to produce a robot that can do the cleaning purposes.	The sensor used to avoid obstacle is autonomous motion used IR sensor	The process of avoiding obstacle and auto path design with simultaneous cleaning feature
Bluetooth Based On Automatic Floor Cleaning System, C.R.Balamurugan*, P.Kirubha, S.ArunKanna, E.R.Hariprasath, C.Anupriya,2018	The conditions needed for floor cleaning in water quantity, and fan, cleanse. With wheeled type machine with movement control.	The module used a LAN wires connected that it connected to the controller and connection of the 12V supply. That might cause a lack of reach of the cable and limited movement	As it , support Bluetooth connection and this module is more suitable for wireless connections

Proposed System:

The proposed system is a solar energy based on a smart vacuum cleaner circuit using Bluetooth module with microcontroller. The system is implemented in the following steps

- Interfacing ultrasonic sensor to microcontroller to control the DC motor.
- Measuring the light intensity using LDR sensor to recharge the battery by the solar panel.
- Sending notification of work done to the user phones via Bluetooth module.

The functional system block diagram is provided in figure 1.

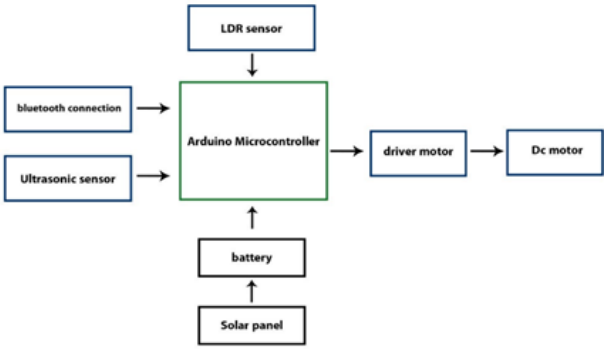

Figure 1. System block diagram

The proposed system consist of two sensors (LDR sensor and Ultrasonic sensor), connected directly to the Arduino microcontroller. The ultrasonic sensor generates the ultrasound waves that moves through the air, if there is any object found that obstruct the movement it will bounce back, it calculates the travel time and the speed of sound to determine the distance, and then sends the information to the microcontroller.

The microcontroller is the brain of the smart vacuum cleaner. The motor driver is an interfacing module between Arduino and DC motors. The microcontroller cannot supply the current required for the motor to function. The increase of current can damage the controller of the motor driver that controls the DC motor and receives information from the Arduino. There are two different sources used at the input of the circuit by interfacing the microcontroller.

The energy source, which provides a push to voltage to get the current flowing in a circuit to start the device to work by electrical energy. The second option of the power source is solar panel that works by allowing photons or particles of light it comprise the photovoltaic cells that convert the sun light into electricity. Moreover, the power source of the device is a solar panel that derive the energy form the renewable sun power source ,LDR sensor can detect the light to which its resistance rises if the intensity of the light decreases , to move by the DC motor rotation to a light source to recharge the solar panel.

System Flowchart:

The figure 2 shows the system flowchart. And the process starts at the vacuum power is on. The DC motor will start moving forward and the ultrasonic sensor will detect if there is an object.And according to that the device directions will change. When the battery is low the vacuum will stop cleaning and search for a light source . If the vacuum is full ,it will send notification to the user phone via Bluetooth and power off the vacuum.

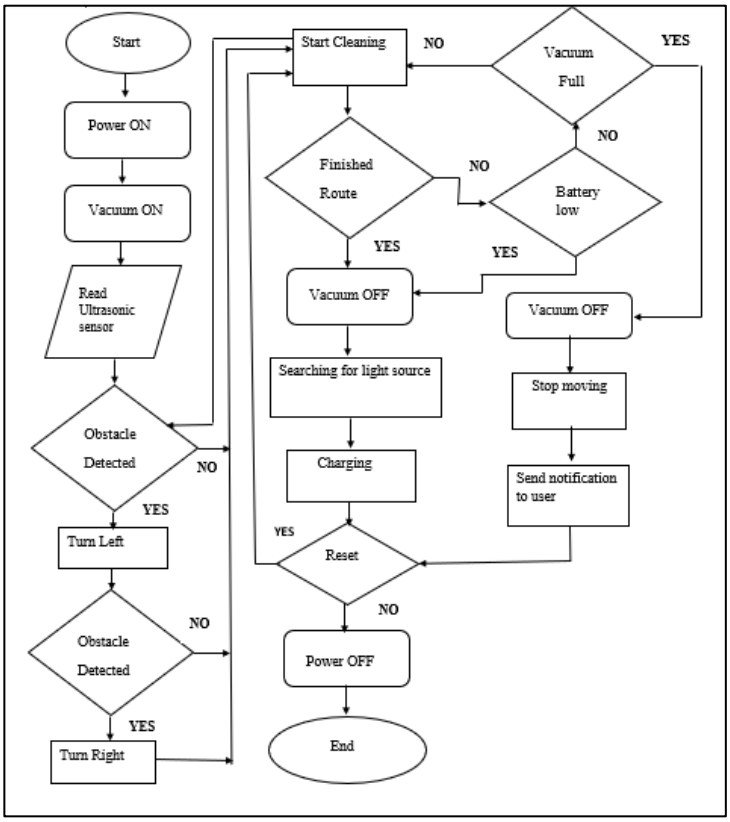

Figure 2. System Flowchat

Simulation and Testing:

Figure 3 shows the circuit diagram of the solar powered smart vacuum cleaner.Different test points are also illustrated in figure 3 . Test point1 illustrates the connection of the power source by using the solar panel. Test point 2 driver motor and DC motor are connected to Arduino with 12V .Test point 3 is the LDR sensor connected to Arduino analog pin.

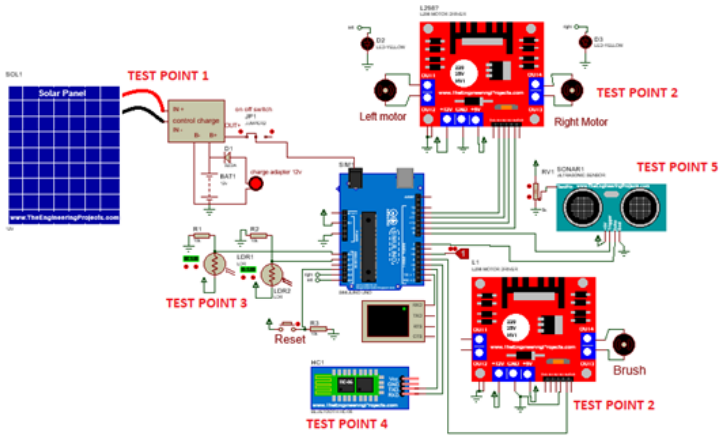

Figure 3. Schematic diagram of solar powered smart vacuum cleaner

Table 2 provides the designed values of each test points as per the data sheet information and the actual simulated values that used in the software.

Table 2. Test points

Test cases at test points	**Design Value**	**Simulation Value**
Test point one ,solar panel connected to control charge and battery to the Arduino	The maximum power voltage 17.4V and the maximum current is around 4A	Voltage 12V
Test point two, 2 driver motor connected to 3 DC motor	Input voltage is around 12V from DC source, 5V is used for power supply for switch logic circuit inside the IC	Voltage applied 12V
Test point 3, two LDR connected to Arduino	Absolute maximum ratings for LDR sensor AC and DC voltage peak is around 100V , and the current is 5mA temperature range -25 C and +75 C	Input voltage 5V
Test point 4 , Bluetooth connected to Arduino	Frequency range of 2.4GHZ , 5V supply voltage	Input voltage 5V
Test point 5 , Ultrasonic connected to Arduino	Power supply require around 5v , and the distance rating 2cm – 500cm , operating current 15mA , 40KHZ is the operating frequency	Input voltage 5V

Simulation Results:

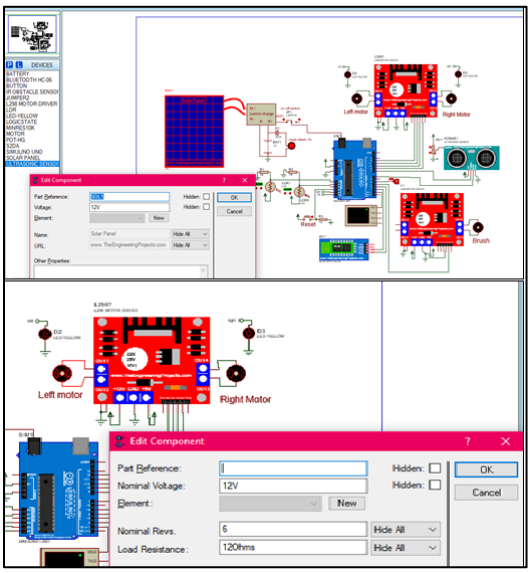

Figure 4. Simulation component screenshot

Figure 4 shows some screen shots of the used voltage for the solar panel and driver motor in proteus software. The Arduino 5V pin is connected to VCC which supply the voltage to the circuit, the ultrasonic sensor type is HC-SR04 that requires 5V VCC connection shown in the circuit diagram, as per as the working of LDR depends on the amount of light is a variable resistor which is input voltage is 5V form the Arduino.

Test case scenarios:

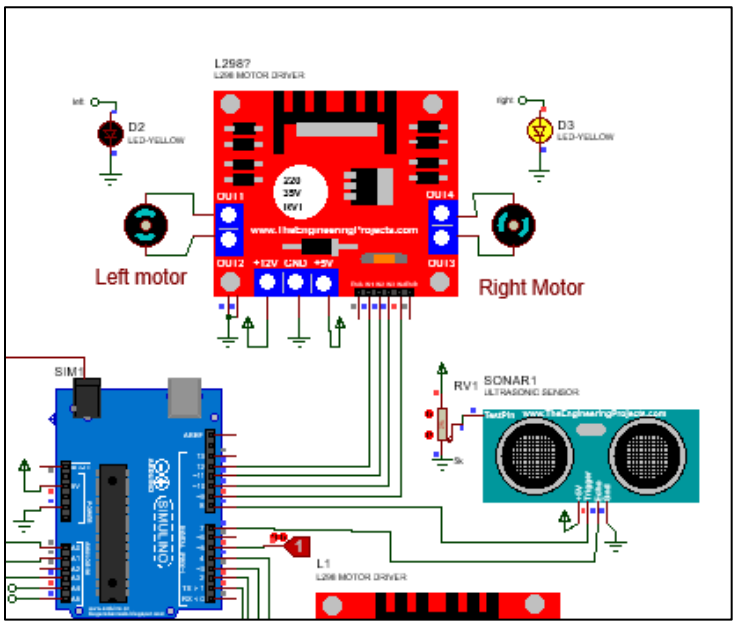

Figure 5. Test scenario 1

Figure 5 shows the achievement of the first scenario, the ultrasonic sensor is interfaced with the driver motor to move the DC motor the LED are connected to show the movement of the vacuum cleaner as following:

- ✓ The normal moving of the vacuum cleaner depends on the distance reading of the ultrasonic and the LED blinks according to it direction, when the distance is less that means there is an block near the sensor which it will avoid it.
- ✓ When the vacuum cleaner storage is full the LED will blink twice and the vacuum is not moving until the vacuum is reset again, as well as when the battery is low.
- ✓ By changing the LDR intensity, the vacuum cleaner will move according to the high resistance of the LDR which is recharging by solar panel and that will accomplish the second objective.

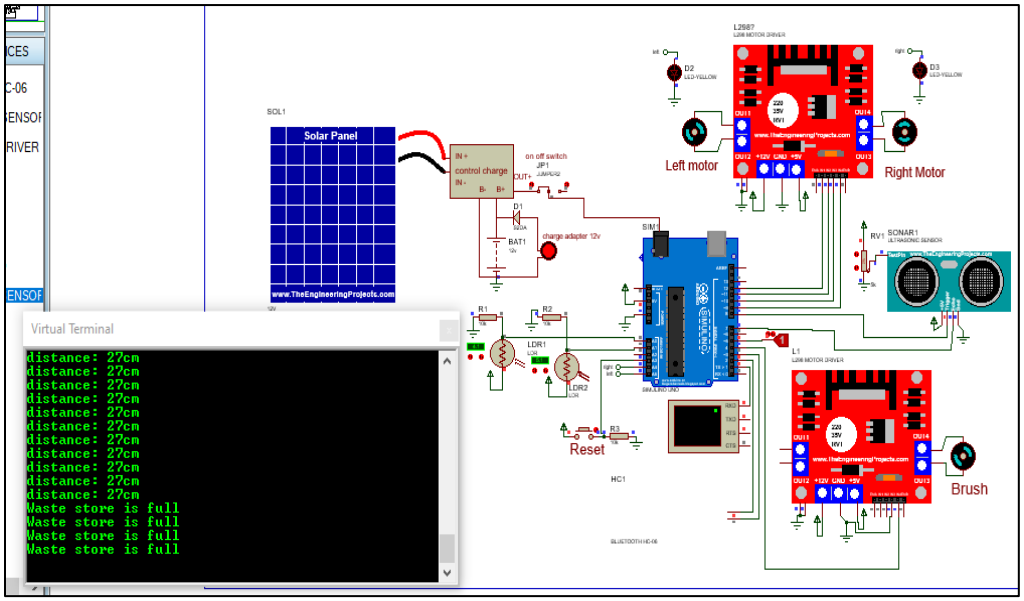

Figure 6. Test scenario 2

Figure 6 shows a virtual terminal display that demonstrate the distance reading of the ultrasonic sensor. When the variable resistance decreases the distance decreases it is a direct proportional to the ultrasonic sensitivity. The Bluetooth notification is shown in the virtual display which shows the message when the waste bin is full and when the battery is low and the light tracking direction which will stop the cleaning and recharge.

Figure 7 shows the LDR connection when there is a change in the value of the resistance the driver motor changes it direction to the near light source. When there is an increase of the resistance value of one LDR sensor when the vacuum cleaner is low battery and need to be recharged, the movement of the DC motor is shown in a virtual display.

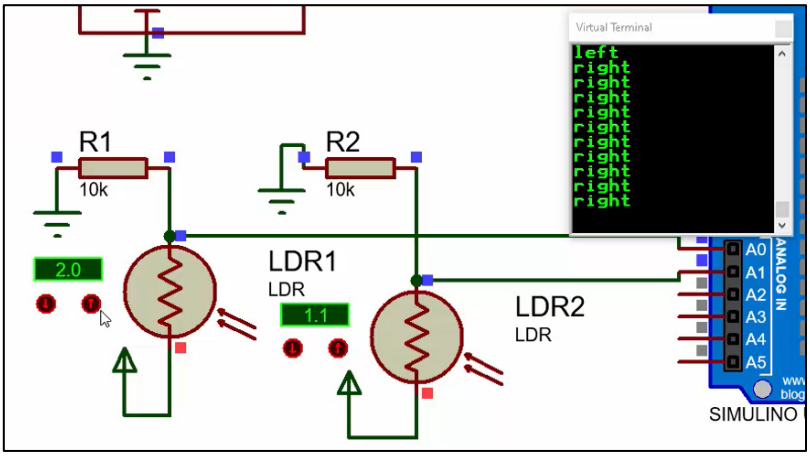

Figure 7. LDR connection

Discussion

The smart vacuum cleaner based on solar panel device is vacuuming the wanted area by the suction part controlled with the driver motor. The Bluetooth notification to the user when the battery is low and when the waste bin is full. The light tracking process to recharge the battery that shown in the virtual display. The DC motor is controlled by using driver motor and avoiding the obstacle by ultrasonic sensor, the movement of the robot is achieved.. The working of the DC driver is achieved in the opposite direction and able to move in different ways. The performance of the ultrasonic sensor can be more accurate with fewer errors using an Arduino and connect it to TMP36 temperature to avoid any damage caused by temperature. The solar panel can improve it efficiency by adding a photodiode that it acts like a mini solar cell in the software. The vacuum cleaner device cleans the required area after the work is done, its sends to the user a notification by the Bluetooth module, which does not require a password to connect between devices.

Conclusion

The system is successfully implemented in terms of the interfacing the ultrasonic with Arduino to control the movement of the device, tracking the light source for recharging the system and sending a notification to the user when the work is done. In features could be improved in different ways, since it is using Bluetooth module that has a low bandwidth WIFI and IOT technology may perform better and it will allow full control to the device, and the microcontroller Arduino can be replaced by Raspberry Pi that can support camera and image possessing.

Limitations

The limitations of the implemented system are

- Ultrasonic sensor is very sensitive to variation in the temperature so when the temperature is high the performance of the sensor will reduce, and some difficulties in reading different reflections from curved, soft, and thin materials.
- LDR sensor has low response in some stable materials it can affect the device to follow the light source to recharge.

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References

Forlizzi, J. (2007, March). How robotic products become social products: an ethnographic study of cleaning in the home. In *2007 2nd ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 129-136). IEEE. https://dl.acm.org/doi/10.1145/1228716.1228734

Afarulrazi, A. B., Utomo, W. M., Liew, K. L., & Zarafi, M. (2011, June). Solar tracker robot using microcontroller. In *2011 International Conference on Business, Engineering and Industrial Applications* (pp. 47-50). IEEE. doi:10.1109/icbeia.2011.5994256

Thomas, S. K., Joseph, S., Sarrop, T. S., Haris, S. B., & Roopak, R. (2018, July). Solar Panel Automated Cleaning (SPAC) System. In *2018 International Conference on Emerging Trends and Innovations In Engineering And Technological Research (ICETIETR)* (pp. 1-3). IEEE.doi: 10.1109/icetietr.2018.8529032

Hwang, J. S. (1996). *U.S. Patent No. 5,568,589*. Washington, DC: U.S. Patent and Trademark Office. https://patents.google.com/patent/US5568589A/en

Hwang, H., Cho, J., Hwang, S. H., Choi, J. Y., & Lee, C. (2019). Design of a Single-Phase BLDC Motor for a Cordless Vacuum Cleaner Considering the Efficiency of Airflow. *Energies*, *12*(3), 465. doi:10.3390/en12030465

Radu, S. (2018). VIRTUAL MODEL OF A ROBOTIC VACUUM CLEANER. *Journal of Industrial Design and Engineering Graphics*, *13*(1), 41-44. available from< https://eds.a.ebscohost.com>

Tun, N. (2019). Design and Fabrication of Mini DC Vacuum Cleaner. *vol*, *2*, 58-64. available from <https://www.irejournals.com/formatedpaper/1701283.pdf>

Patel, D. C., & Patil, H. S. (2017). Development of Arduino Programme Code for Autonomous Smart Vacuum Robot. *EYE*, *360*, 5. available from <https://www.ijeter.everscience.org>

Balamurugan, C. R., Kirubha, P., ArunKanna, S., Hariprasath, E. R., & Anupriya, C. Bluetooth Based Automatic Floor Cleaning System. availablefrom<https://www.researchgate.net/publication/324528763_Bluetooth_Based_Automatic_Floor_Cleaning_System>

Sukumarana, A., & Mb, A. A Brief Review of Conventional and Deep Learning Approaches in Facial Emotion Recognition. *Artificial Intelligence for Internet of Things*, 101.