International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 10 | Oct 2021 www.irjet.net p-ISSN: 2395-0072

AIR PURIFIER INTEGRATED WITH ROBOTIC VACUUM CLEANER

Aasim Shaikh[1], Ovez Momin[2], Ammaar Solkar[3]

[1]*Student, Dept. of Automobile Engineering, M.H Saboo Siddik College of Engineering, MH, India*
[2]*Student, Dept. of Mechanical Engineering, M.H Saboo Siddik College of Engineering, MH, India*
[3]*B.E, Dept. of Mechanical Engineering, M.H Saboo Siddik College of Engineering, MH, India*

Abstract- *Since the onset of industrialization and modernization increasing air pollution has become a major concern for all countries alike. The impact of air pollution on human health varies from person to person and can cause severe complications. Air pollution, specifically indoor air pollution has become world's biggest environmental health risk linked to around 4 million deaths annually from illness such as stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer. A major contributor to indoor pollution is not only the contaminants present in the air but also the pollutants such as dust, dirt , particulate matter, pet dander , etc. present on the household floor .These two factors ; pollutants in air and pollutants on the floor play a major role in polluting the environment of common household. The suggested strategies to improve indoor environment is the usage of air purifiers and vacuum cleaners but due their high cost and high power consumption they become inaccessible or unaffordable to the common man. Therefore in order for these devices to become an actual solution to the aforementioned problems they must be economical and efficient .Hence in this paper we aim to present the design and production of a low cost high performance smart air purifier integrated with a robotic vacuum cleaner. The apparatus mentioned in this paper not only purifies the indoor air but also cleans the household floorings from any kind of particulate matter that maybe present on it.*

Keywords: **Air Purifier, Vacuum Cleaner, Indoor air pollution, Filter, Algorithm.**

1. INTRODUCTION

With increased modernization there is greater emphasis being laid on the importance of living a healthier life. But with modernization and industrialization, the resultant air pollution acts as a major hindrance in achieving that goal. The effect of air pollution on health is complex and the individual impact varies from one person to another. In recent studies it has been shown that it is not only the outdoor air quality but also the indoor air quality in rural and urban areas that are causing health concerns [1].According to the World Health Organization (WHO) report in 2021, it reveals that around 4 million people had died prematurely solely due to illnesses arising through indoor air pollution [2]. According to 2014 study of Electrolux group it showed that habits, preferences, activities, personal possessions also have a significant impact on the indoor environment. Having a dog equals traces of excrements, playing sports equals traces of grass or clay, wearing shoes indoors created higher particle level in general [3]. The study suggests that a vacuum cleaner is a good tool for maintaining a clean home environment. So it becomes very necessary in today's day and age to use devices such as vacuum cleaners and air purifiers in order to curb indoor pollution .Hence we have come up with a device which combines two such appliances: Air Purifier and Vacuum Cleaner, which are useful in reducing indoor air pollution. The device specifically uses single suction motor (fan) to take in the ambient air in order to purify it and also to suck in (vacuum) the particulate matter present on the floor. Therefore this single suction motor can perform both the functions. The device is portable and collects external data from sensors mounted on it and uses the data to make various movements according to its navigation algorithm. While navigating and cleaning, the device avoids obstacle, walls or stairs which are detected by the infrared sensors.

The aim of this study is to design and implement a low cost high efficiency integrated device with inexpensive and easily accessible mechanical and electronic components. Generally, only basic switches are used as sensors in low cost vacuum cleaners for detecting obstacles. Our designed device, though being low cost, makes use of infrared sensors that enable the device to detect obstacles before they hit them.

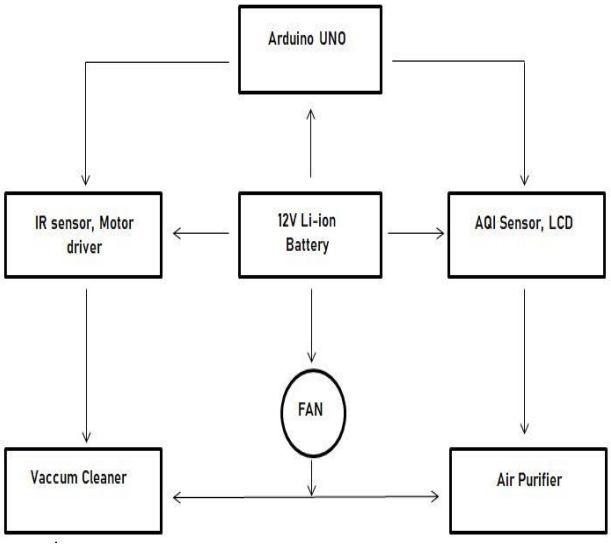

Fig.1. Block Diagram of the working of device

2. OVERVIEW:

The device consists of different units and components like Filtering unit, Controlling unit, Suction motor, 2 DC motors with wheels for movement of the device along with a plastic outer body.

2.1 Filtering Unit

Generally particulate matter of different sizes needs to be filtered in such cleaning devices because of which multiple layers of filter are needed to be provided. The proposed device makes use of 3 different filters that make up the filtering unit, namely: Pre-filter, Charcoal filter, Air filter cartridge. The roles of the different filters are described below.

- Pre-Filter:

  The pre-filter material is the first layer of purification the device where large sized particles are filtered. The pre-filter material used is an FDA (Food and Drug Administration) approved surgical mask cloth. The FDA approved mask materials are generally categorized in into two types: The high and moderate barrier mask materials having a >98% filtration efficiency for particulate filtration efficiency (PFE) and bacterial filtration efficiency (BFE) while low barrier mask material has a >95% filtration efficiency for BFE only [4].

- Active carbon filter:

  Carbon filtering is a method of filtration that uses a bed of activated carbon that removes impurities from a fluid flowing through it. Activated carbon filters out odor, pollutants and volatile organic compounds (VOC) from the air by trapping the gas molecules and efficiently removing them from circulation [5]. It is capable of adsorbing household chemicals, smoke, carbon dioxide etc. Typical particle sizes that can be removed by carbon filter ranges from 0.5 to 50 microns. S.B Divate [6], mentioned in his study that activated carbon is having the most adsorbing capability than any other adsorbent.

- Cartridge Filter:

  The final filter used in the body is cartridge air filter which is made up of pleated paper which acts as the filter material. Because of cost constraints and lack of availability of required size of HEPA filter we have used a bike air filter for filtering purposes as it nearly meets the same criteria of performance. The auto industry is now shooting for an initial efficiency of around 98 percent, meaning the filter stops 98 percent of the dirt it ingests [7]. The filter material used is capable of trapping dust and particles of sizes as small as 5 microns. The filter being a vehicle air filter is highly effective in trapping any kind of smoke or odor that may be present in the air. The filter used is 5 inches in diameter and is 4.5 inches high.

2.2 Control Unit:

As the name suggests, the control unit generally helps in controlling the device and helps to carry out the required tasks accurately. It helps to convert the data received by the sensors and uses it to command the microcontrollers to manoeuvre or control the device as per need so the required task is completed properly. The control unit in our device consists of different sensors such as Infrared sensors, an air quality sensor along with LCD i2c display, 2 DC motors for movement of device, L298N motor drive for controlling the speed of the DC motors and a microcontroller for controlling the entire setup. The microcontroller used in the device is Arduino Uno R3

- Infrared sensor:

An infrared sensor is an electronic device that emits infrared rays in order to detect the aspect of the surroundings. An IR sensor can measure the heat as well as the motion of the object. The IR sensor (infrared) sensor includes an IR LED and an IR Photodiode, so by combining these two, an optocoupler can be formed. IR LED is one kind of transmitter that transmits infrared radiation while an IR photodiode is dissimilar as compared to usual photodiodes as they simply detect IR radiation.

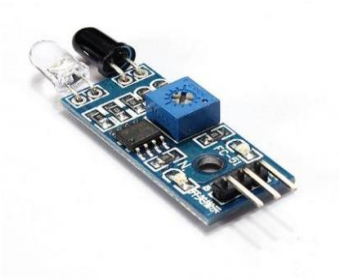

Fig.2. Infrared sensor

- Air quality sensor:

The air quality sensor used in this device MQ-135. It is an air quality/ gas sensor module capable of detecting harmful gases present in indoor spaces such as homes and offices. The MQ-135 gas sensor can sense gases such as ammonia, nitrogen, oxygen, alcohols, aromatic compounds, sulfide and smoke. It is capable of detecting such gases and can provide results in the form of particulate matter (PPM). The operating voltage of this gas sensor is from 2.5V to 5.0 V. The MQ-135 gas sensor can be implemented to detect the smoke, benzene, steam and other harmful gases.

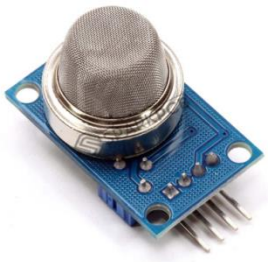

Fig.3. MQ 135/ Air quality sensor

- L 298N Motor drive:

L 298N Motor drive is a high power motor driver module for driving DC and stepper motors. L 298N Module can control up to 4 DC motors or 2 DC motors with directional and speed control. The motor driver used in our device is Dual H-bridge Motor driver which helps in controlling the speed and direction of two DC motors simultaneously. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

- I2c LCD Display board:

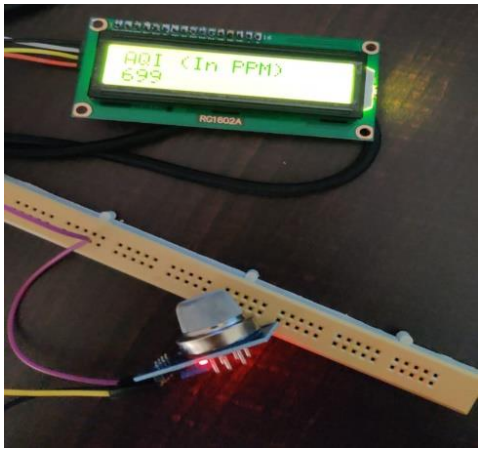

Fig.4. i2c LCD

The display board used in this device to display the data collected by the sensors to user is16x2 i2c LCD display board. The 16x2 i2c LCD screen is using an i2c communication interface. It is able to display 16x2 characters on 2 lines, white characters on blue background. The i2c is a type of serial bus developed by Philips, which use two bidirectional lines, called SDA (Serial Data Line) and SCL (Serial Clock Line). Both must be collected by pulled-up resistors. The usage voltages are standard as 5V and 3.3V.

- Arduino Uno R3:

Arduino is an open source physical computing platform. Arduino UnoR3 is a one of kind of AT mega 328P based microcontroller. It is based on simple I/O board and on processing/wiring language implementing development environment. It makes use of 14 digital I/O pins along with 6 (PWM) pins. The no. of analog I/O pins used on it are 6 as well. It incorporates 32 KB

of flash memory along with 0.5 KB of memory used in the boot loader. The recommended input voltages for this microcontroller range from 7 to 12V.

2.3 Suction Motor

The name of the motor suggests the purpose of the motor in cleaning devices that is to vacuum/suck in the surrounding air into the device. The proposed device makes use of a single suction motor to perform the clearing function of both air purifier and vacuum cleaner. The suction motor used in this device is Nidec Ultraflo series H92C-A7. The device consumes 12 volts of input voltage and requires a power input of 9.36 amperes.

3. WORKING

The working of the device is based on the principle of combining the 2 said devices; air purifier and vacuum cleaner and making them compact and mobile while using least possible amount of energy for their functioning. The device makes use of 2 switches to control the function of the device. Initially when the first switch is pressed, the device starts, it is the air purifier out if the 2 devices that starts functioning using the suction motor. It takes in the surrounding air into it and uses multiple layers of filters to purify and clean the air off its contaminants while using the same suction motor to also dissipate out the cleaned air back into the room. When the second switch is pressed, the vacuum cleaner module comes to life which also consists of motor assisted sweeping mechanism that is commonly used in robotic vaccum cleaners to efficiently clean the floor. It starts using the infrared sensor to sense any kind of obstacle that may be present in front of it and uses that data to move around the room while cleaning it simultaneously.

Fig.5. Constructed body of the device

The working of the proposed device can be divided into 2 parts:

1. Air Purifier: The air purifier is turned on when the first switch of the device is pressed. The air purifier makes use of the suction motor to take in (suck) the surrounding air into the filter. The speed of the suction motor can be controlled in two ways; manually by a regulator and in an automated way by an AQS (Air Quality Sensor). The AQS senses the air quality index of the surrounding air and accordingly fluctuates the operating speed of the suction motor.

If the air quality index of the surrounding air is set to be high, the AQS sends this data to microcontroller which in turn causes the operating speed of the suction motor to increase so that more amount of air can be taken in to get purified through the filter. Once air quality index of the surrounding air starts to improve, the AQS using its data helps to reduce the speed of suction motors since it does not require to operate at a higher speed taking more amount of air inside.

Once the air with the help of the suction motor has entered into the filter chamber of the device it first passes through the pre filter material which helps to trap particularly large amount of particulate matter that may be present in the air. Once the air has passed through the pre filter material, it enters into the activated carbon filter which is not only helpful in removing contaminants but also helps in removing any kind of odor that may be present in the air. It is particularly useful and helpful in removing household chemicals, smoke and dust that may be present in the air. Once the air has passed through activated charcoal filter, it enters into the final filter which is the cartridge paper filter which is used to remove small as well as large size contaminants and moisture that may still be remaining inside the air. Once the air has passed through the different filter layers of the device, the suction motor is used this time to dissipate the clean and purified air back into the room.

An I2C display module is used, which is fixed on to the external body of the device and is used to display the air quality index which is sensed by the AQS.

Fig.6. Before and after images of the chamber used for air purifier testing.

2. Vacuum cleaner: Once the second switch is pressed, the vacuum cleaner mode of the device turns on. It consists of a sweeping mechanism which assists in vaccuming of the floor surface. It makes use of two DC motors attached to the lower end of the device close to the vaccuming nozzle. It has brushes attached to the shaft of the DC motors which help in sweeping the floor surface and bringing the dirt closer to vaccuming nozzle. The device in itself is capable of moving around the room in long S pattern (snake pattern) while cleaning it. It is one of the easiest methods to cover the given area of a room for cleaning hence it has been used.

The device makes use of line follower method to manouevre around the room in the long S pattern. The specific method for movement of the device has been selected because of cost constraints as it would require high end sensors and microcontrollers to make device move around the room and map it independently. For testing purposes a white mat consisting of black taped lines in long s pattern had been stuck on it. The device with the help of its motors and IR sensors follows the contrasting black lines on the white mat to move around the room. Whenever an object/obstacle appears to come in front of the device, the IR sensors through its infrared radiation is able to detect its presence and causes the device to stop moving forward/backward until the obstacle has left its path. This setup actually follows the method of existing robotic vaccum cleaning devices that make use of cameras along with other sensors that follow a given tape assisted path that is usually applied to the ceiling of a room that is to be cleaned.

The nozzle that is used for vaccuming has been designed in such a way that it consists of a tunnel chamber just behind its opening .The tunnel chamber is provided with external threads that can be closed with the help of a threaded cap. This tunneling chamber is used to store the dirt and the dust that is collected during the vaccuming process. Once the vaccuming process has been completed the threaded cap can be removed from the nozzle body which in itself can be removed from the device to empty out the dirt that got collected in it. This helps in saving space inside the device and makes it compact by eliminating the dirt box which is generally used to collect the dirt as the nozzle itself performs the function.

The driving mechanism of the device consists of two DC motors along with an L298N motor drive. Different types of driving mechanism were available to be chosen from such as differential drive, skid steering, synchronous drive, Ackermann steering, etc. Out of all these we chose to use the differential drive since it is the simplest and the easiest to implement [8]. Also it provides arbitrary motion and in place rotation (zero radius) however its main disadvantage is the difficulty to maintain straight line motion due to independent motors, to ensure the straight line motion, identical motors should be used and the center of mass should be in the middle of the robot. The differential drive of the device consists of two individually driven wheels mounted in one line which are opposite to each other. Also Castor wheel is added to balance the robot. Each wheel is controlled by a different motor to make different movements such as forward, reverse rotating, left and right. The speed of the individual motors can determine the direction of motion.

There are three different cases for the motion of the robot according to the individual motors speeds [9]. In case one; if the motors have the same speed and rotating in the same direction the amount of torque produced on both wheels are the same resulting the robot moving forward or backward. In case 2; if the motors have the same speed and rotating in the opposite directions torque generated on both wheels are equal in magnitude and opposite in direction resulting the robot rotating around itself left to right. In this case the center of rotation is equidistant between the motors. In case 3; if the motors rotate in the same direction but have different speeds the robot starts running towards left or right depending on the motor that have higher speed. For example if the left motor has high speed then robot turns towards right side or vice versa. [10]

Fig.7. Device operating as a vaccum cleaner

4. RESULT

Once the construction of the body had been completed using its mechanical and electrical parts, the working of the device was carried out successfully without any issues or deformation of the chassis.

To test out the working and efficiency of the device, the device was put through several tests. For once, the device was put in a chamber measuring 100 sq.ft filled with smog made up by burning paper bits and coconut threads. The device took around 15 minutes to clear up the smog filled in that space and replace it with considerable fresh and clean air. The initial air quality of the smog filled room was 107 measured by the device's aqi sensor which is considered unhealthy for sensitive groups. After a run of 15 minutes, the aqi of the chamber dropped to 65 units, which is considered to be moderate. Similarly, the device was also tested for its vaccuming ability. The test resulted in successful calibration of the device as it was moving in the required straight line and was also easily following the given curves on its provided path. The suction power of the device was found to be 0.5 m/s which is equivalent to 8.59 cfm. It was found to be good enough to clean/vaccum pet food off the floor. Also, running the suction motor at its maximum capacity resulted in it producing noise recorded at 71 dB.

Table No.1. Specification of the device.

Dimension	27 x 27 x 24 cm
Battery life	30 minutes
Noise level	71 decibels (max)
Suction power	8.59 cfm
Movement	Snake/Line follower

Fig.8. The result of noise level test of the device

5. CONCLUSION

In this paper, the detailed construction, working and testing of the device was presented. The paper described about the hardware and software used for construction, the description of the working of the device such as the algorithm and modes of working and different tests conducted on it such as suction power test, noise level test, air quality test etc. The device successfully cleared all the tests and performed satisfactorily in it both its operation as an air purifier and robotic vaccum cleaner. The device required only a single suction motor to carry out all its functions thus requiring very less amount of energy for its operation. The device was also found to be having no installation difficulties and is designed to be user friendly. The future scope of improvements for the said device include developing an app to control and navigate the device and help it to map the room independently, using more and better quality sensors and microcontrollers for movement optimization along with using industry level materials for body construction.

REFERENCES:

[1] Prof. Mahesh D.S, Ashwimi Rajesh Kamath.B, Ashwini M.S, Naresh Holla.N, " Self sustainable air purifier with air cooling system", International journal of Engineering Research and technology, Volume 7 Issue 10, 2019.

[2]https://www.who.int/news-room/fact-sheet/detail/household-air pollution-and-health.

[3] https:// www.electroluxgroup.com/en/using-vaccum-cleaners-to-investigate-indoor-pollution-18680/

[4]Samy Rengasamy, Adam Miller, Benjamin.C Elmer, Ronald.E Shaffer, "Filtrastion performance of fda cleared surgical masks", Journal of International society of respiratory protection, Volume 3, 2009.

[5]Sheng Bo Ge, Zhenling Liu, Yuzo Furuta, Wanxi Peng, "Characteristics of activated carbon remove sulfur particles against smog", received 16 November 2016; revised 17 December 2016; accepted 18 December 2016.

[6]S.B Divate, R.V Hinge , S.R Kadam, "Removal of heavy metal (phenol) by using various adsorbents", International Journal of Scientific and Engineering Research, volume 5, issue 7, July – 2014 ISSN 229-5518

[7]https;//www.rv.com/archive/the-truth–about-engine-air-filteration/

[8]Dudek G, Jenkin M [2010] Computational principles of mobile robotics. Cambridge university press. ISBN-13:978-0521692120

[9]LaValle SM [2006]. Planning algorithms. Cambridge university press. ISBN-13:978-051124133-8

[10]Anil Eren, Hatice Dogan,"Design and implementation of a cost effective vaccum cleaner robot ", Turkish Journal of Engineering 6 [2], 166-177, 2021

BIOGRAPHIES:

Aasim Shaikh is currently pursuing his bachelorette degree in automobile engineering from M.H Saboo Siddik College of Engineering, Mumbai, India

Ovez Momin is currently pursuing his bachelorette degree in mechanical engineering from M.H Saboo Siddik College of Engineering, Mumbai, India

Ammaar Solkar is a bachelor of mechanical engineering from M.H Saboo Siddik College of Engineering and is currently working as an IT professional in a data analysis company.