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Self-Power Generating Indoor Air Purifier Robot

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Abstract: The increase in air pollution has led to an enhancement in need & usage of air purifier. In the past two years, especially in the months of October and November, the usage of indoor air purifier has increased drastically in National capital region of India when particulate matter has crossed the acceptable limits. The raise in indoor air pollution had led to severe concerns to elderly people, infants and asthmatic patients even if they stay back at home. Commonly static room air purifiers are used, but a movable air purifier which can sense the location of higher concentration of air pollution and move the system accordingly can improve the overall efficiency of the air purifier. This type of air purifier needs electricity to run. This paper proposes a self-power generating air purifier robot, which is capable of electricity generation, sensing air quality and air purifying by moving it to desired location. Hence this robot can be utilized both by urban and rural area people. The robot has four components namely, renewable energy generation module, air filter module, sensory module to sense the presence of PM 25 particle to determine how much air purification is required and finally data analytics module which will help in identifying the location where air purification is to be done.

Keywords: Air purifier, Air quality, Sensor, Self-power generating unit, Data Analytics

1. INTRODUCTION

Increasing urbanization has shown significant negative impact on the air quality. With rapid industrialization and decrease in forest reserved areas, the quality of air has been severely compromised. Good air quality is a must for the healthy human and their well-being. Presence of particulate matter commonly called PM and emission of harmful gas like NO_2 and CO significantly harms human lungs and other organs [1]. World Health Organization (WHO) reports [3] are reflecting various health issues in humans due to air pollution. According to the report, air pollution is the cause of death of 8 million people every year. The major source of death, i.e., 54% is due to household air pollution and 46% die because of ambient air pollution. The household air pollution leads to various health issues. As the clean and fresh air is very important for physical and mental health, the need of the indoor air purifier has drastically increased in metro city of India [5, 6]. The indoor air purifier is considered as good equipment for improving the air quality of the house and maintaining the health of the people [2]. By using IoT technology and fast data analytic approach, the engineers are able to develop an intelligent-control technology, the hardware and software design and application of the new kind of intelligent digital air cleaner.

Health experts are advising using air purifiers, especially for infants, elderly people and allergic or asthmatic patients. A significant improvement in health of allergic or asthmatic patients is observed if they sleep in healthy and filtered air [4]. The use of advance technology and understanding the types of air pollutants has helped to develop efficient indoor air filters. These air filters are able to provide a controlled environment in the house. These air purifier need power to run and are usually static in nature i.e., kept at one place in the room. The more effective air purifier will be the one which can move as per the air quality index. For designing a mobile air puffier we need a battery driven system. The aim of proposing this model is to find a solution which has low running cost but there is no compromise on efficiency. The proposed robot has a self-power generating unit. Different renewable energy sources are optimally used to generate the electricity which provides the power to the robot. Thus, the model has both advantage of no external power need and also the mobility of robot is maintained. The sensors are used to monitor the environment and data analytics is used to analyze the data collected from various sensors and to control the movement of the robot.

The motive of this paper is to propose an indoor air purifier robot which is capable of electricity generation using natural phenomena and purifier the air. In the remaining paper the system is proposed and implemented in section and 2 and 3. The working of robot and observations are discussed in section 4. The robot uses sensor to monitor the quality of air and purifier the air

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accordingly. The data collected by sensors are analyzed for recommending the smart working of the suggested robot. The advantage of proposed approach is discussed in section 5.

2. Proposed System

The system broadly has two major parts; the first generates electricity and second purifies the air. Both the mechanisms are smart and can adjust to provide maximum productivity with less electricity consumption and increase efficiency. For power management one of the main sources of electricity generation for the robot is solar energy and also other renewable sources are considered for power requirements. But as the solar intensity varies from place to place and sun gives different light intensity at different time of the day so the robot has to be smart to adjust with this change in light energy intensity and for this purpose the robot is equipped with an LDR sensor which is and light gives different pulsating value based on different light intensity. As with an increase or decrease in intensity of light electrons are excited at different bands and hence varied resistance value is acquired. So using this principle the microcontroller gets to know where the light intensity is high.

With 4 different LDR sensors, the robot gets to know light intensity different in front, back, left and right and based on this difference the robot moves to the best possible location and hence getting the maximum light intensity.

The second mechanism i.e. smart air purification works on the principal of robot localization using an antenna to detect different locations at which the robot is and the mapper collects data from sensors like PM2.5 and MQ125 to know air quality from each location. Each location is then clustered and based on each location, mean value clusters are ordered and given different priority and based on the priority the robot is commanded using Bluetooth or Wi-Fi to move to the desired location distance from the antenna by avoiding obstruction using the ultrasonic sensor. As soon as the robot reaches the desired location it stops there and begins purifying the air and hence reducing the clusters to the lowest priority. As the air quality reduces to the acceptable range the robot then moves to the other location where the cluster value is the highest. Resulting in a smart, efficient and low power consuming air purification inside the home. Figure 1 explain the workflow of the proposed system.

The proposed system architecture has four different modules named as Air purifying module, Power management module, Sensor Module, Data Analysis Module. In remaining section we will study the components used in each module.

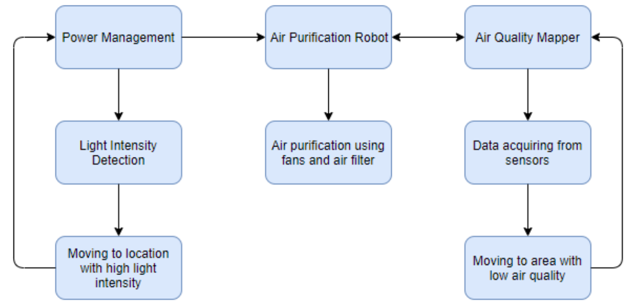

Figure 1. Workflow of proposed system

A. Air purifying module

Different filters are used in literature and market to purifier the air. The filters used in this paper are given below

1) Carbon Filter: Carbon filter uses the method in which activated carbon materials or sheets are used in order to filter out the impurities from the air. As the air passes through the activated carbon the pollutants stick to its surface and hence clean pollutant-free air is released out. Carbon filters are not only useful in purifying the air containing the contaminants but also are also useful as they help in removing odors from the surrounding indoor.

2) HEPA filter: HEPA filters in the proposed solution are used performs two ways of air purification that is suctioned in by the fans. First, the proposed solution uses two or more filters that work like an air filtration membrane whose function is to stop the larger particles like of dirt, dust, and small hair of dogs and humans that if inhaled over a long period of time can cause life-threatening problems. Each filter have some paper like folded filters inside it, this helps by trapping the smaller particles once the air passes through it and the out air is clean and particles free and hence is healthy and breathable. The paper-like the filter is made of a material which is like very dense glass fibers. This HEPA filter uses three different techniques to trap and filter the air and free it from dust particles as the air passes through it. When particles are moving at high speed they get trapped directly inside the fiber, while others get attached simply as they pass by the filter. On the other hand, when the particles are at low speed they tend to wander about randomly around the filter (this random moment is known as Brownian motion) and tends to stick to the fibers.

3) Cloth sheet like AC filter: Spun fiberglass, pleated paper or a simple cloth placed inside cardboard is used to make an air filter. It is used to trap particles which are visible to the naked eye or are greater than 2.5ppm.

4) Bacterial filter: The device is a contraption designed to trap the dust particles and kill the microorganisms by using positively charged elements to attract the negatively charged particles. These filters strain the particles through microscopic pores and fibres, thus effectively trapping the dust and other pollutants. The most significant advantage is that it traps the airborne contaminants including dust, pollen, spores, bacteria, and viruses.

B. Power management module

Renewable energy resources are exploited by the scientist to meet the power need of the day [7]. A combination of various sources used in the system are

1) Solar Cell: Solar cell devices also known as photovoltaic cell has ability to convert energy of light into electrical energy [8]. Solar cells are fabricated with silicon which increases the efficiency and lower the cost of the materials used in solar cells [9, 10]. Materials are made of amorphous, or polycrystalline, or crystalline silicon. Solar cells do not have any moving parts, or requires fuel or any chemical reactions to take place for the production of electrical energy.

2) Piezoelectric sensor: The piezoelectric sensor works on the concept of the change in force, pressure, and strain and this change are used for the production of electricity [17, 18]. This sensor is used for the three main operations namely shear effect, transverse effective and transducer effect.

3) Dynamo: It uses the concept of electromagnetism for the production of electricity. Dynamo is used as an alternator which produces an output is the form of an AC power [11]. Dynamo works on the principal where a magnet is used, either a permanent magnet or electrical magnet is rotated under the direct presence of another magnetic field [12]. These magnetic fields are illustrated using flux lines. A dynamo generates electricity with the help of a stationary magnet known as a stator to produce magnetic influencer and a rotating magnet known as a rotor that works as a distorter which cuts through flux lines produced by the stator. When the magnet which is rotating cuts through flux lines produced by stator then electricity is produced.

4) Light Dependent resistor (LDR): Techniques to trap and filter the air and free it from dust particles as the air passes through it [13]. When particles are moving at high speed they get trapped directly inside the fiber, while others get attached simply as they pass by the filter. On the other hand, when the particles are at low speed they tend to wander about randomly around the filter (this random moment is known as Brownian motion) and tends to stick to the fibers.

5) Thermoelectric module: The thermoelectric module has produced electricity using the thermoelectric material which is inside the circuit [14]. A thermoelectric module uses has thermoelectric materials which it uses. One type of material is negatively charged semiconductor (n-type) and the second type of material is positively charged semiconductor (p-type). This n-type and p-type circuit inside the thermoelectric module helps in continuous circuit current flow which further helps in electricity generation. These two n-type and p-type semiconductors form a thermoelectric pair but are not in the form of a p-n junction. Both have a figure of merit and have tight controlling properties.

C. Sensor Module

The smart working of the system is controlled by use of sensors. A variety of sensor are used to sense air quality and control the motion of robot. The proposed solutions use LDR sensor, Ultrasonic sensor, TEG Module, Air quality sensor like MQ 135, PM2.5 sensor, Carbon sensor, Bluetooth module. For the purpose of air quality management, the devices use a tactic that it makes the house using GPS module and at each location, it also stores the air quality and based on the map different clusters are created for a different region. Each region is then ordered based on its toxicity level. After that, the device decides the location based on the location and clusters. Where the air quality is too bad the device stops and purifies the area using air filters embedded inside the device and by using the air inlet and air outlet and hence smarty manage the air quality in a specific region.

Different sensors help in making a smart decision based on data from MQ 135, PM 2.5 and Carbon sensor smart decision is made. Whereas sensors like LDR, ultrasonic sensor and TEG module help in the interaction of the device with the physical world and help in the conversion of free energy into usable electric energy and avoiding obstruction [19, 20].

D. Data Analysis Module

The purpose of this module is to record and analyze the air quality status at different location. Based upon location and sensor data, the device classify different house area based upon its air quality and time. After analyzing data for 24hrs, it will automatically learn about the high polluted and low polluted areas. Based upon its learning, it moves at different location at different times to purify the air quality.

3. METHODOLOGY

How the design proposed in previous sections is actually implemented is described in this section. Four different modules that were discussed in the design section are developed and assembled as a single robot. The four different modules are implemented as follows:

A. Power Generation Module

In this model, there are 4 different power generation modes i.e.

- Generation using thermoelectric module
- Generation using solar panels
- Generation using dynamo
- Generation using piezoelectric material

Figure 2 depicts the proposed system. All the power generation sources produce a variable DC output. To control the DC output voltage regulator is used [15, 16]. A regulated voltage from different sources is attached directly to a battery charger unit with the in series connection of diode. Then the battery is connected in parallel to the voltage booster. The positive and negative terminal of battery and voltage booster is connected in series with the battery charger. A small micro-controller is then connected to the battery for the purposes of battery charge monitoring.

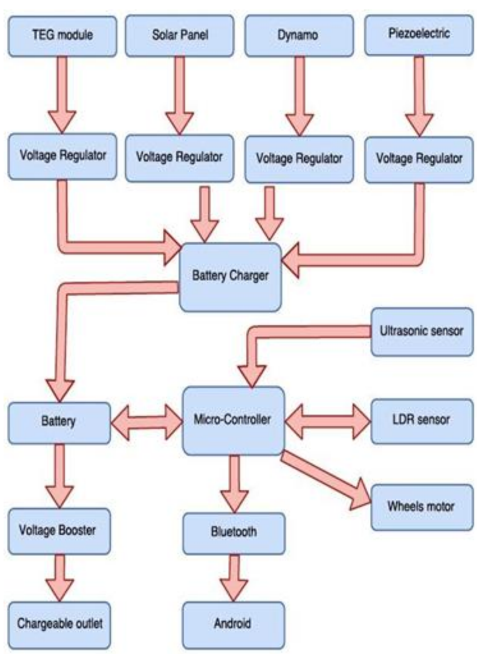

Figure 2. Proposed model architecture for electricity generation

The micro-controller has an extended Bluetooth module that is used to communicate the data directly to a smart phone using an application over BLE hence making it wireless. A motor is also attached to the microcontroller using its I/O pins which help the robot with the movement. Ultrasonic sensor will be used to detect obstruction around the robot and avoid them while moving. An LDR sensor will be used to detect the best concentration of sunlight to be provided to the solar panel when the concentration of sunlight is reduced the LDR sensor will detect it and automatically moves to the place with high concentration of sunlight, this make sure the highest production of solar electricity. While a dynamo will be constantly moving inside using the concept of magnetic motor and constantly producing electricity. A piezoelectric material will be attached to the wheels to produce electricity while moving. While a TEG module will be used to produce electricity with the help of heat. All the electricity generated will be stored in a lithium-ion battery.

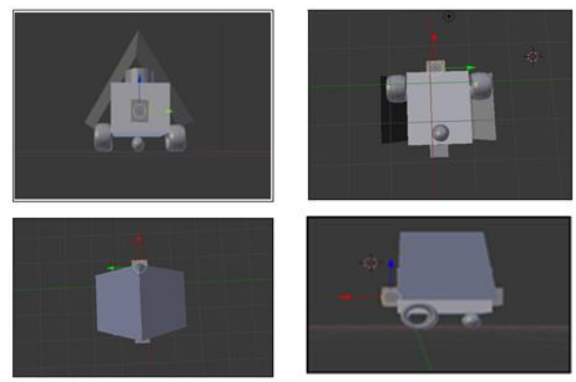

Figure 3. Views from different angles

The electricity thus generated can be utilized either using a USB 3.0 output or by simply detaching the battery out and replacing it with an uncharged battery inside the battery holder. Figure 3 shows the front, top, bottom and back view of the proposed model, the triangular hut-like structure will be where the solar panels will be places, the cuboidal shape will be the box where the microcontroller and Bluetooth module will be placed and the battery charged will be made available there. The cylindrical structure inside the cuboid will be the dynamos rotating with the help of magnets will be placed. It also shows the bottom view of the model, two side cuboid attached to the model will be the TEG module will be placed. It shows the top view and at the top, there will be an LDR sensor and the side view along with the ring- like structure depict wheel mechanism of the robot and small ball is the caster wheel to support the model.

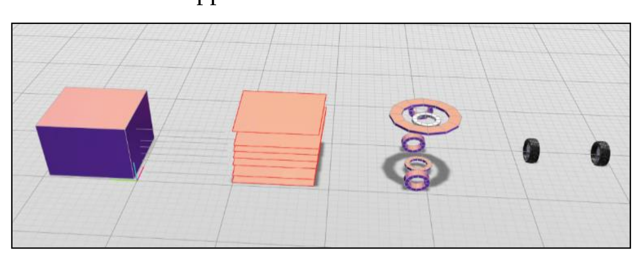

Figure 4. 3D model of the device

Figure 4 shows the 3D model of the device. The solar panels are placed at the top in slant position so as to make sure maximum absorption of sunlight in every possible direction, while the TEG module is placed on the body and close to the ground to convert maximum possible head generated in process of dynamo rotation and heat from the floor. Proper balance of the model is taken care of, and a better model can be made by making the body of the model covered with solar cell or more TEG modules. Figure 5 shows the actual device photograph.

Figure 5. Actual Device View

1) Capability: Two or more 30v solar panel of 300watt are connected in series with in parallel connection of dynamo attached to magnetic plates of 6v each connected in series rotating with the help of permanent magnet in middle. Two or more TEG modules which produces 20watts of power at 14v connected in series and in parallel connection with piezoelectric material. All the four sources are connected in parallel with each other and the output will be a parallel sum of total 60v for a miniature model and can be increased up to 200v.

$$\sum V_S + \sum V_T + \sum V_P + \sum V_D = \sum V\text{total}$$

Where V_S = Input voltage for solar panel

V_T = input voltage from TEG module

V_P = Input voltage from piezoelectric material

V_D = Input voltage from dynamo

Vtotal = Total Voltage output

Figure 6. (a) Circuit Design (b) Model Design

A prototype was created based on the defined mechanism as shown in figure 6(a) and 6(b). Figure 6(a) shows the circuit connection of the designed model where multiple sources are connected to a battery charger with a step up voltage booster and charging the Li-Po battery controlled using microcontroller. Figure 6(b) shows the running model supported by three 12v, two TEG modules, 2 dynamos and several piezoelectric materials.

2) Air Purifying Module: Figure 7 shows the flow of air through the filters and how the unhealthy air travels from the bottom and as it passes through the filters it gets purified. The idea is to avoid the contact of huge particles, moisture, and dust to get in direct contact with expensive carbon and HEPA filters and to bind all the filters together. As the air is drawn inside by the fans. The fan on the above creates a route for air to flow, and first air come in contact with the cloth sheet, here most of the dust particles greater than 2.5 micron, hairs and moisture is separated from the air and made to settle in the plate below, while the second anti bacteria layer removes disease- causing bacteria's from the air. Now the air travel through the carbon filter which is an excellent harmful gas and purification agent which active charcoal in it. After all this finally, the air travels through the HEPA filter which removes particles of size 2.5 micron from the air and clean and fresh air is released out by the fan above the robot. The cycle is repeated.

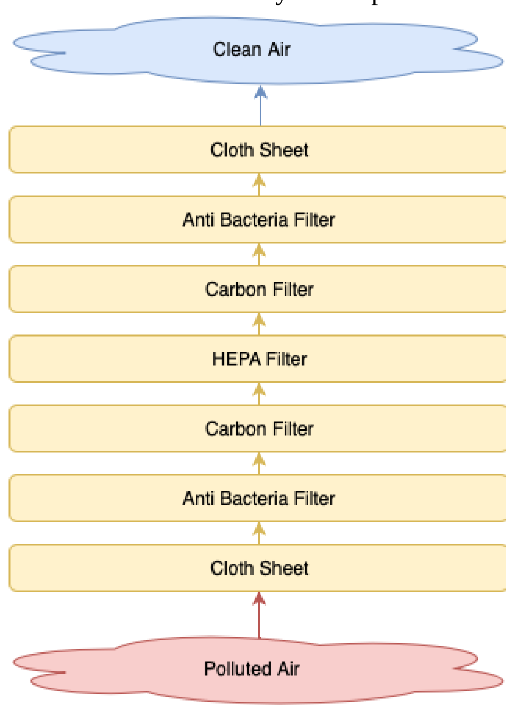

Figure 7. Flow of air through the filters

Figure 8 shows the 3D visualization image for the filter process and the possible enclosure. Here there will be holes for the purpose of air circulation through the filters.

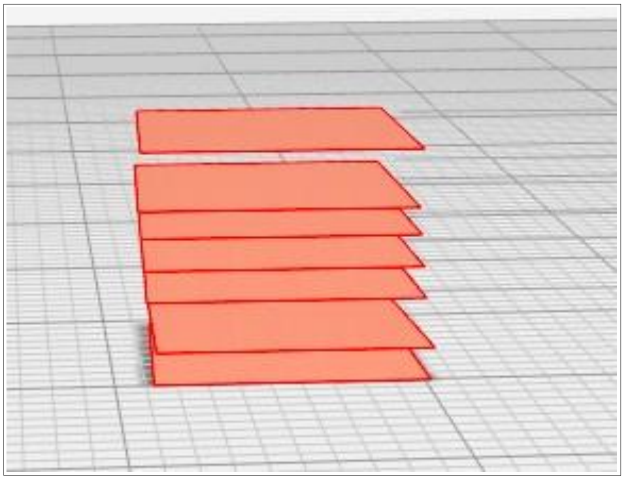

Figure 8. Filters Layer

The carbon filter will be surrounding the HEPA filter while it is surrounded by an anti-bacterial filter and a cloth and normal ac filter to bind every filter together. By doing this the larger particles, dog hairs, and water molecules would not pass through the cloth and normal filter resulting in a long functional filter

3) Data Analysis Module: Figure 9 shows the snippet of the generated dataset. Where the duration is in IST format HH:MM:SS AM/ PM, and value is recorded after each five seconds later allowing us to have a huge data set to visualize and learn about the functional capability of the robot in real time environment. The generated date is of the Diwali duration where an increase in air quality index is expected, hence such high quality index is normally noted. The end result is calculated on the basis of this setup only. The experiment was done on two different days.

- A Normal Day
- A Day after Diwali Festival

The next section shows the PM 2.5 increase on a normal day recorded by the sensors when running for few hours, hence it can easily visualize a decrease in air quality on a normal day.

4) Sensor Module: The air will start from below and start lifting to above hence getting purified in the process of flowing through the system. Figure 10 shows a pseudo code written onto the micro-controller to control the speed of the fans. In case of high pollution level detection, the fans will function more hence the air flow through the filters will be more resulting in faster purification and lowering of air quality index.

Time	AirQuality (PPM)
12:00:00 AM	348
12:00:05 AM	350
12:00:10 AM	351
12:00:15 AM	350
12:00:20 AM	347
12:00:25 AM	350
12:00:30 AM	351
12:00:35 AM	352
12:00:40 AM	354
12:00:45 AM	354
12:00:50 AM	354
12:00:55 AM	355
12:01:00 AM	355
12:01:05 AM	355
12:01:10 AM	353
12:01:15 AM	355
12:01:20 AM	349
12:01:25 AM	356
12:01:30 AM	357
12:01:35 AM	356
12:01:40 AM	354
12:01:45 AM	349
12:01:50 AM	353
12:01:55 AM	337
12:02:00 AM	353
12:02:05 AM	353
12:02:10 AM	355
12:02:15 AM	354
12:02:20 AM	353
12:02:25 AM	355
12:02:30 AM	355
12:02:35 AM	354
12:02:40 AM	354
12:02:45 AM	345
12:02:50 AM	355
12:02:55 AM	353
12:03:00 AM	354
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12:05:00 AM	353
12:05:05 AM	354
12:05:10 AM	344
12:05:15 AM	355
12:05:20 AM	354
12:05:25 AM	360
12:05:30 AM	352
12:05:35 AM	354
12:05:40 AM	353
12:05:45 AM	351
12:05:50 AM	350
12:05:55 AM	348
12:06:00 AM	349
12:06:05 AM	348
12:06:10 AM	345
12:06:15 AM	345
12:06:20 AM	345
12:06:25 AM	343

Figure 9. Snippet of the generated dataset

Figure 10 shows 5 set of rule conditions for different levels of air quality index.

```
if ( sensorValue <= 50)
{
  analogWrite(Fan, 200);
}

else if ( sensorValue > 50 && sensorValue <= 100)
{
  analogWrite(Fan, 450);
}

else if ( sensorValue > 100 && sensorValue <= 150)
{
  analogWrite(Fan, 600);
}

else if ( sensorValue > 150 && sensorValue <= 200)
{
  analogWrite(Fan, 800);
}

else if ( sensorValue >= 201 )
{
  analogWrite(Fan, 1000);
}
```

Figure 10. Code to control Fan speed

4. Working of the Robot

The robot is now installed in a real world scenario. The entire process of air purification, power generation and data analysis is explained in the following section. The Figure 11 shows the lifecycle of the robot. The robot is switched on, as explained in the power generating module. The robot then moves in the room and senses the quality of the air. The data recorded while sensing air quality is stored in the data mart, which is further used for trend analysis of the air quality by using machine learning algorithms. If the air quality is found to be less than the threshold value, the air purifier module is switched on and after purifying the air for that particular location, the robot moves to different location and the process keeps on repeating. However, if the air quality is found to be above the threshold value, the robot is switched off as no purification is needed.

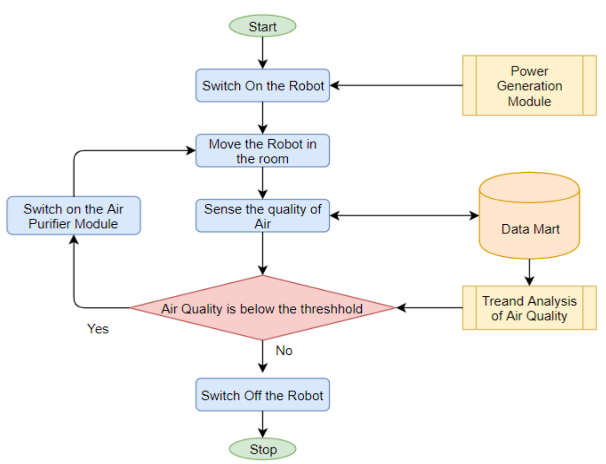

Figure 11. Flowchart of the System

The initial PM2.5 started at between PM 2.5 value of 270 and 280, while the lowest recorded value for PM 2.5 is around 263 and the highest recorded value is 322. There is a drastic raise noticed in PM 2.5 value from 290 to 315. As the robot was continuously moving and hence the graph was plotted. The graph shows such a variation in air quality as because initially in first run the robot was turned ON and OFF to measure how that affects the air quality when the robot was turned ON and when the robot was turned OFF. Initially for few minutes robot was kept turned ON with fans tuned OFF to measure the average air quality of room and that was between 340 to 360, after that fans were turned ON which can be seen in the initial stage where there is a steep negative slope in graph which projects the air quality increased drastically and reached as low as 270. After few minutes an average between 270 and 290 was achieved and below that the robot needs to be supplied with external source of power to function hence the robot was turned OFF and positive slop can be seen as soon as the robot turns OFF that projects that the robot actually functions and was able to reduce the extended particles and actually made the air quality better. After the robot was turned OFF the highest value for air quality was about 320. A graph was plotted after a run for one hour, that shows that even though the robot utilized the self-produced electricity it was able to reduce the extended particles, remove bacteria's and harmful gases from the air and managed to attain air quality value of about 90 to 95 lesser than its environment, later test and data visualized graphs will show more improvement and better understanding of the ability of purifying of the robot. It can be concluded from figure 12 that robot was able to deliver much better air quality in the time span of fewer than 20 minutes and that is on its own produced electricity from heat, solar energy, and kinetic movement.

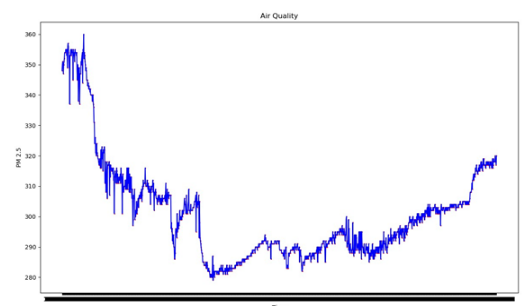

Figure 12. Data visualisation for the PM 2.5 increase on a normal day in few hour (Test one)

Figure 13 shows the data graph visualization for after the fans and airflow was stopped that helped in understanding in course of an hour after the robot reduced the extended particles and harmful gases and bacteria's from the air in what time will the air quality begin to get back to that of outside environment of the room. This time also the air quality sensor inside the robot was made functional for an hour. With the lowest value achieved as 260 and highest being 320. The difference here is of about 60. The reading from the sensor was achieved with a gap of five seconds each and the data was being collected for an hour that makes a total of 720 values used for the construction and visualization of this graph.

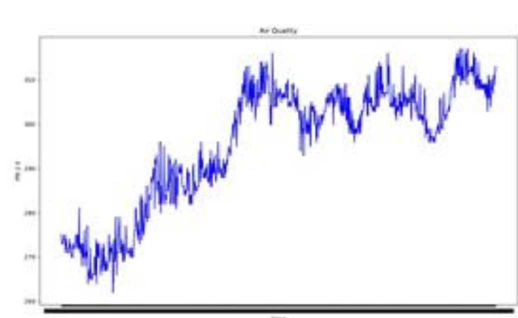

Figure 13. Data visualisation for the PM 2.5 increase on a normal day in few hour (Test two)

This graph helped in understanding that after the average value was achieved or point where there was no more or little reduction in sensor data for PM 2.5 was seen the robot fans were turned OFF in order to study the post-purification effect in the air quality of room when the robot is absent. The robot still travelled to different points to collect data so as to create an average. Figure 12 gives a valuable insight and it can be easily concluded that the robot even though was turned OFF still the increase in PM 2.5 value was as low as 60 in the duration of one hour. This tells us about how efficient the robot purification ability is given that the robot was completely dependent on the charge from its battery charged from free sources of energy, and was able to even re-utilize its energy in form of heat and producing motion. The later section shows data collected from the duration around Diwali and at the day of Diwali. The highest recorded value for air quality on the day of Diwali was recorded as high as 999 that is twenty times larger than the recommended air quality index for humans to live a healthy life. But the data collected shows different scenario for indoor air quality index for a 250 square meter room.

The robot has functionality that it moves around the house and cleans the air by removing the PM particles and gasses using the filter. The robot has a feature that it stops at the place where it detects the air quality to be bad and purify the air, for this purpose the air quality sensor is attached directly on to the robot as compared to the previous test where the sensor was attached in surroundings inside the room, this helps in proper understanding of what is happening around the robot. Data collected on the day of Diwali is plotted and shown in figure 13. As expected here the higher and lowest value of PM 2.5 is exceptionally high as compared to other days. The highest value is over 410 which is 9 times greater than the recommended value while the lowest value is around 330 which is 6 times greater than the recommended value.

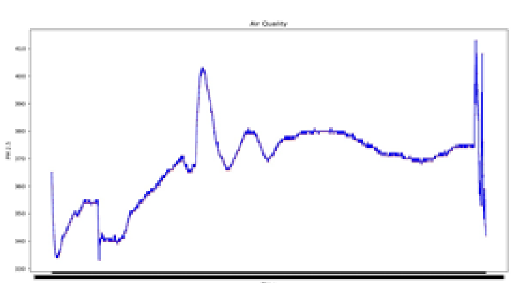

Figure 14. Data visualisation for the PM 2.5 increase on a normal day in few hour

All the data generated and plotted is for the indoor environment only collected for 4 hours hence figure 14 is obtained. This data collected proves that as soon as the robot stops purifying the air the quality of air begins to change simultaneously, reason can be either diffusion that leads to the forced movement of PM particles and other gases from outdoor to indoor with low concentration so the robot need to be run all time to maintain a standard air quality. This data is from sensor attached on the head of the robot collect data by moving around the house showing that not even a same room have same air quality value, initially the value begins with 365 and then decreases to 335and then after few minutes it increases again to 352 then to 355, then later a sharp drop in value is noticed resulting in value of 330 and as the robot leaves that point the value of beings to increase and drop at different point inside the room. This data can help in proper planning for different points inside the room that are less affected after the robot stops purifying air and the algorithm shown in figure 15 can function in specific points which are more prominent to change with air quality. It explains an algorithm that if the air quality at some point is greater than its previous one then the robot stops at that point and purifies the air, the robot looks for consecutive five values of air and if those 3 values are same then robot takes it as mean and add it to previous one making a new minimum point value to wait until that value is achieved the robot keeps on purifying air by stopping its movement. The idea is to have maximum efficiency by saving to robots internal energy for other processes.

```
while ( currentAirQualityValue >= (airQualityValue - 10))
{
 digitalWrite(Wheels, LOW);
 temp[0] = sensorValue;
 if(temp[0] == temp[1]) && temp[1] == temp[2])
 {
  digitalWrite(Wheels, HIGH);
 }
 else if(temp[0] != temp[1])
 {
  temp[1] = temp[0];
  temp[0] = sensorValue;
 }
 else if((temp[0] == temp[1]) && temp[1] != temp[2])
 {
  temp[2] = temp[1];
  temp[1] = temp[0];
  temp[0] = sensorValue;
 }

 airQualityValue = (airQualityValue + currentAirQualityValue)/2;
}
```

Figure 15. Algorithm to maintain mean air quality

The while loop will run until the current air quality is greater than or equal to an average of current and previous air quality minus one. This helps in maintaining a mean air quality level throughout the area. Sensor value is the value from air quality sensor attached to the robot and if the vale is same for 3 consecutive sensor values the robot wheels will be set HIGH and the robot will start moving again inside the area for the detection of air quality less than the meanwhile the fans will we continuously purifying the air. This process will run infinitely until the robot's battery drains off or the user turns the robot OFF. Based on the algorithm other two graphs are obtained that are shown in figure 16 and figure 17. These graphs are generated based on the values obtained on the day of Diwali hence the value for PM 2.5 is reaching as high as 500. The graphs are explained in the next paragraphs.

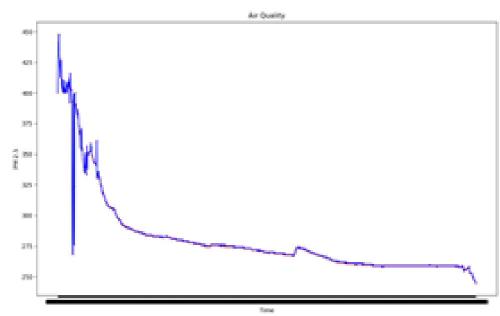

Figure 16. Data visualisation for the PM 2.5 increase on a normal day in one hour (Test Four)

The motive of the other two tests related to figure 16 and 17 is to smartly conserve electricity while maintaining the uniformity throughout the area. The graph is shown in figure 16 initially begins with a very high PM2.5 value that is 400 which is 20 times greater than the recommended value for air quality and PM 2.5 value in the air. And quickly that raised to 50 more that is 450 after that the robot purifies the air and was able to bring the value back to 400 and quickly in 15 minutes was able to reduce the value to up to 300 which is 1.5 times lower than the initial value. In a later stage the motive was to maintain uniformity throughout the room was achieved later in 20 minutes as can be seen from the graph in figure 16 that there is a low steep slope in the graph from value 300 to 250. Here robot was able to reduce the value to 200 PM 2.5 in an hour-long run test.

Figure 17 shows a graph for the test where the closed environment was opened in between the test to see how better the robot performs when the external air is allowed to enter inside the room in between the process of purification and how better the algorithm shown performs in this test. Initially, the values for PM 2.5 start in between 350 to 400. The robot was able to maintain the average value for the PM 2.5 in a few minutes an hour-long run test to 300 that is 1.25 times. After the average was achieved and no further changes in the value was notable then the closed system (closed room) was opened (doors open) there was a steep rise in air quality levels was discovered that is as high as 550 which is 22 times greater than the recommended air quality level and is hazardous to breathe in. The robot here also tried to maintain an average throughout the region and stopped and performed air purification process in different regions of the room which can be seen with a steep downward slope of the graph and the lowest achieved value for the air quality PM 2.5 particles here is 350 while the average varies between 350 and 400.

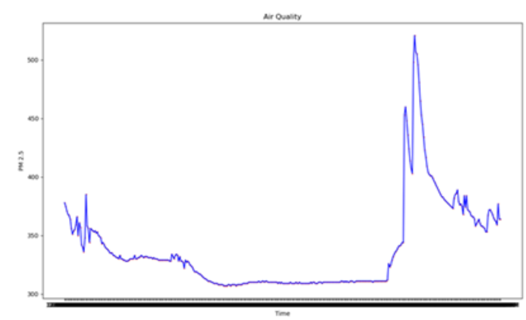

Figure 17. Data Visualization for the PM 2.5 increase on a normal day in one hour when room was opened in between test (Test five)

5. COMPARISON WITH EXISTING SYSTEM

The existing system consists of stationary non-electricity generating air purifiers. These available purifiers are not smart and continuously consumes electricity and are unable to maintain standard average throughout the coverage area. These purify are low in efficiency in electricity consumption, on the other hand, the proposed methodology in this research work allow the robot to be highly energy efficient while being smart and generating its own electricity. The robot is able to maintain uniform air quality level of in the closed region. Table 1 shows the comparison table for the available system and proposed system based on various factors.

TABLE I. COMPARISON WITH EXISTING SYSTEM

Factors	Available Technology	Proposed Technology
Cost	High cost	Low cost
Smart	Not smart	Highly smart
Efficiency	Low	High
Power consumption	High	Low
Electricity generation	Not available	Can generate
Controllability	Not available	Can be controlled using Arduino and programmable switches.

6. CONCLUSION

The system will be successful in harvesting electricity from natural sources and from situations where most of the energy is wasted in form of heat or normal human activities. Activities which are ignored and are not taken into account very much are considered to harvest electricity hence reducing the wastage of energy in form of heat, regular movements, and solar energy. Providing different means of electricity generation while keeping the environment safe is not the limit of this model. As the increase in efficiency is the ultimate goal, and to achieve that goal use of technologies like machine learning and artificial intelligence will be used to help the robot to make better judgment and learn about environment over the time so that the effect can be increased and allow the robot to automatically predict locations in a given zone where the concentration of sunlight is most at the specific time and it can automatically move to that coordinate rather than moving around and relying on LDR sensor and searching different locations hence consuming more electricity. By this, the robot can consume less electricity for the task like moving and sensing and save more electricity in the battery hence increasing productivity and eventually making the robot smarter. A robot huge and more powerful can be built on farmlands, with huge dynamos and huge solar panel to cultivate more electricity in short period of time. It can be concluded from the above test in section 6 experimental setup that robot has high efficiency in the closed system and was able to reduce the PM 2.5 particles along with hazardous gases from the air in an hour-long run test and maintain a standard air quality throughout the room.

The average reduction in PM 2.5 value is around 150 values in case where the air quality is above 200 but below 300 on the other hand in case of air quality between 400 and 500 the robot was able to maintain a standard air quality of 200 and 250. It can hence be concluded from test that robot can reduce value of to 200 in an hour in case of closed system. While in case of an open system even though being variable the air quality still remains in the range of 200 and 250 and is highly variable in between these two but does not increase than 250, which makes the robot highly reliable when running for more than one hour can give much better results. Having microcontroller as its brain the robot is able to run several many algorithms which makes the robot smart and helps in the smart consumption of electricity and smart airflow and air quality manipulation.

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