HOWARD UNIVERSITY

Senior Design Final Report

Autonomously Mobile Air Purifier

Submitted by:

Raymond Jones
Warren Spencer
Kenneth Booker

Von Miles
Charles Brown

Instructor: Dr. Charles Kim

Date Submitted:04/23/2014

Mobile Air Purifier

We certify that this is an accurate Final Report and we are in agreement that this report is an accurate representation of the project.

____

Name **Signature** **Date**

____

Name **Signature** **Date**

____

Name **Signature** **Date**

I certify that this report is an accurate representation of the project and I approve it.

____

Advisor/Instructor Name **Signature** **Date**

Contents

Introduction

The air inside the home is generally dirtier than air outside since a house is a closed-off environment. For those with allergies or asthma this poses a big problem. Forced air and heating systems only circulate dust particles and other pathogens around the house. Current air purifiers in the market are stationary or just oscillate from side to side like a fan. There is a high chance that the air purifier is just filtering the available air in the room and, therefore, more air purifiers may have to be installed to filter the whole house--depending on the size of course. Most purifiers today are always running and having to buy multiple is a major inconvenience to the customer. With much thought, the idea to make a mobile purification device came about after looking at the designs for the automatic vacuum. The mobile air purifier will be relatively the same concept except instead of cleaning the floors this device will be cleaning the air.

Air purifiers are devices that eliminate contaminants from the air, thereby instigating a cleaner, safer environment. These devices are commonly marketed as being beneficial to allergy sufferers and asthmatics, and at reducing or eliminating second-hand tobacco smoke. Commercial grade air purifiers are manufactured as either small stand-alone units or larger units that can be affixed to an air handler unit (AHU) or to an HVAC unit found in the medical, industrial, and commercial industries. Air purifiers may also be used in industry to remove impurities such as CO_2 from air before processing. Dust, pollen, pet dander, mold spores, can act as allergens, triggering allergies in sensitive people. With the advancement in technology, air purifiers are becoming increasingly capable of capturing a greater number of bacterial, virus, and DNA damaging particulates. Air purifiers are used to reduce the concentration of these airborne contaminants and can be useful for people who suffer from allergies and asthma. There are many types of air purifiers; the most commonly used are s a filter-based purification which trap airborne particles by size exclusion. Air is forced through a filter and the filter physically captures particles and electronic air cleaners use an active electronically enhanced media to combine elements of both electronic air cleaners and passive mechanical filters designs.

Problem Formulation and Current Status of Art

I. Understanding Problem: Air pollutants are hazardous to those inhabiting the air space. EPA states that some toxic chemicals released in the air such as benzene or vinyl chloride are highly toxic and can cause cancer, birth defects, long term injury to the lungs, as well as brain and nerve damage. Each day, air pollution causes thousands of illnesses leading to lost days at work and school.

II. Identified Need: A system that is able to purify the air reliably, efficiently, selectively and simply.

III. Research the Status of Art: Currently, in the market there are already high-tech air purifiers.

- Airocide
- Oreck Airstincts

Note: Observations showed that both air purification units are stationary and are limited to one room.

IV. Determine our Requirements: We want to further improve on the current air purifiers by making them able to detect air-quality in multiple rooms and move towards the source of corrupted air by using a wide range of transmitters, sensors, receivers, a mobility kit, and a processor. Maneuverability, Reliability, cost efficiency, and simplicity are the goals to reach for this system's design.

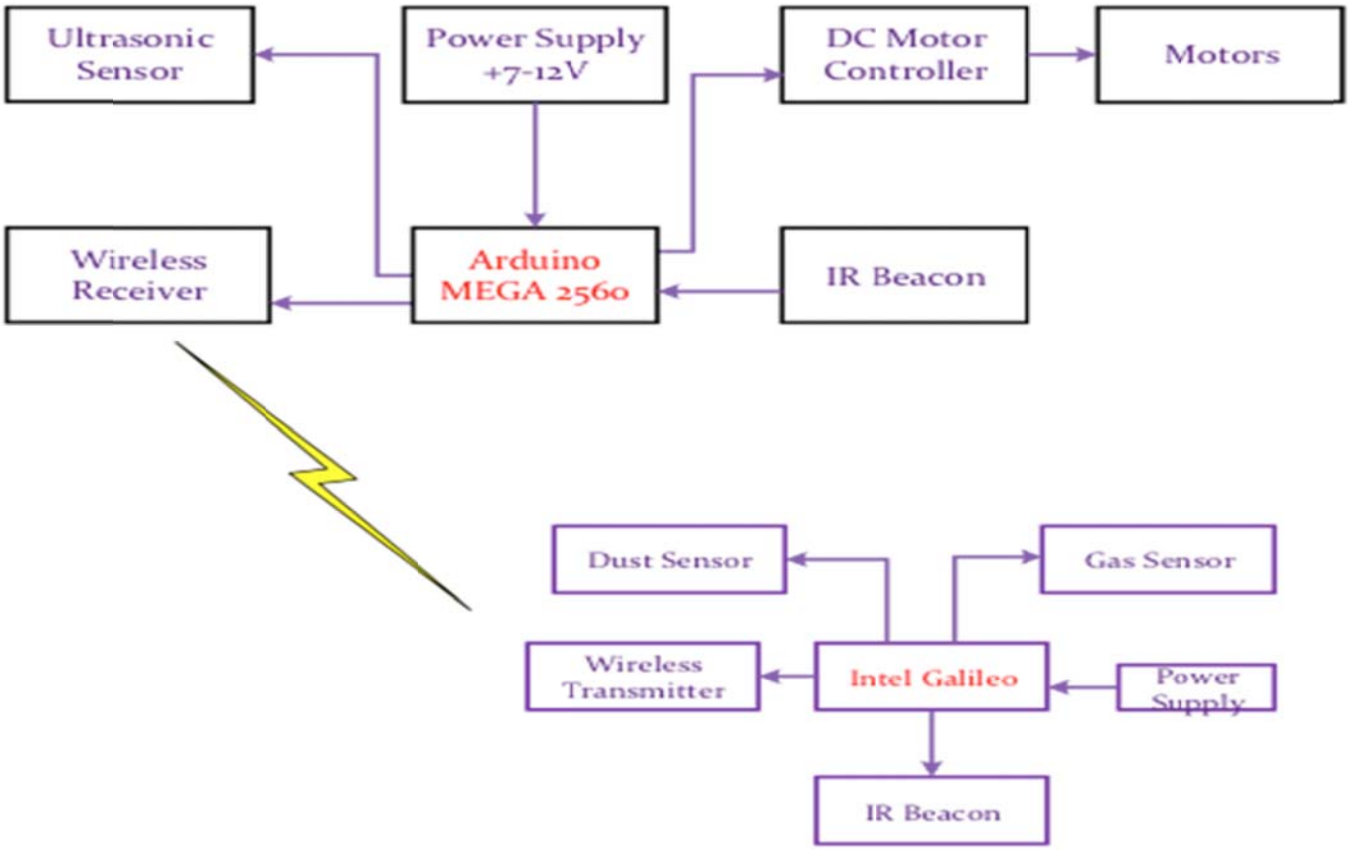
As of today, Air purification comes in many forms such as UV germicidal irradiation, activated carbon meshes, ionizers, and much more; however, none that was researched seemed to be mobile. So far, all air purifiers on the market are stationary and it is interesting to note how this project's idea has not been implemented as of yet. Here are some examples of current stationary air purifiers:

- Airocide—the harmful gasses emitted by products in the home (cleaning supplies, paints, even air fresheners) are concentrated in the purifier's densely packed matrix of highly reactive catalysts that destroy the pathogens on contact. Nothing captured, nothing cleaned.
- Oreck AirInstinct 200—has a sensor that checks the particles in the air passing through it and automatically changes the airflow rate of the purifier.

Constraints and Criteria of the Design Requirements

The system is required to be fully automated and, in order to do that, we need a base with a motor, a motor controller, ultrasonic sensors, IR Beacons, and a Microcontroller. We plan to have this device locate various air-quality sensor arrays installed around the home that read unclean air using a gas sensor and a dust sensor. The array will have its own beacon and microcontroller.

The design schematic is the following image:



The current design of the device has the following constraints:

- Poor maneuverability: Due to the use of only one ultrasonic sensor the device has many blind spots in which it would not detect obstruction a certain angle away from it.

- No selectivity: On ECE day we only used one sensor array for a demo; however, if we were to have two arrays and both were activated the device would not know which one had a higher precedence to go towards.

- Motor controller inefficiency: As of right now the device has a motor controller that is only able to spin the motor forward. The second motor controller does not have this problem thankfully.

- Energy inefficiency: The IR beacons we got did not have a location/proximity detection features that would allow the beacon to know when they were in close proximity of each other. As a result when the device got close to the sensor array's beacon it would spin around continuously searching for the IR Beacon location; therefore, needlessly expending energy.
- Floor restricted: There should only be one mobile air purifier system in a one story home. It would not be cost effective to buy multiple mobile air systems; furthermore, at this point it may cause communication problems.

Solution Generation and Selection of Top Design

A great engineering solution is one not only based on demand but also functionality, simplicity of use, compliance to necessary standards and its capabilities. Considering these objective functions helped to solidify the idea of what the mobile air purifier should be able to do. To generate a great mobile air purifier, all of the objective functions were implemented in the design of the mobile air purifier.

In terms of its functionality, the mobile air purifier must sense when the air-quality in a given environment reaches values below an assigned threshold value. Furthermore, when the air-quality value goes below the threshold, the mobile air purifier must also successfully travel from its current location to the vicinity of wherever the poor air-quality reading is detected; that is, provided that the terrain is flat and agreeable enough for the device to travel on without causing any problems. When multiple areas report values below the threshold value, the mobile air purifier design must be able to distinguish which area, if any, has the greatest degree of air pollution.

Another key feature in the mobile air purifier design is its user interface. The mobile air purifier must have an easy interface that will allow the user to set his desired threshold value that will alert the mobile air purifier that the air within a certain area is polluted. Also, the user interface will allow the user to easily turn the mobile air purifier on and off. The mobile air purifier must be capable of averting obstacles in its direct path and comply with the latest standards for purification rate.

The following table depicts the objective functions that we desired the mobile air purifier to fulfill.

Function	Requirements
Functionality	➢ When the beacons sense the air quality goes under the threshold the purifier will come and clean the air.
User Interface	➢ Able turn on/off
Capabilities	➢ Able to turn on and off by itself when the sensors alert the system ➢ Able guide through obstacles to purify air
Compliance	➢ Purification rate based the standard air quality for a space

After selecting the objective functions that the mobile air purifier will meet, the next phase of solution generation is to choose which device components best fit the requirements of the design. In trying to select an appropriate chassis for the mobile air purifier design, the cost, maneuverability, maximum payload, reliability and power consumption were all criteria used to distinguish the best option. Developing a decision matrix and ranking the various options made it even easier to decide which chassis was best. Likewise, in selecting a device that would detect obstacles in the path of the mobile air purifier, the cost, power consumption, reliability, compatibility, accuracy, range and ease of programming are all factors that weigh into the decision.

The following table depicts the various options for the robot chassis and their scores based on certain criteria.

1= not good, 2= ok, 3= great

Base	Cost	Maneuve r-ability	Max - payload	Reliability	Power – Consumpti on	Program -ming	Total
Treaded Base-Drive	1	3	2	3	3	3	15
2 motor drive	3	3	3	2	2	3	17
4 motor chassis	2	2	2	3	3	3	16

The following table depicts the various options for obstacle detection and their scores based on certain criteria.

1= not good, 2= ok, 3= great

	Cost	Power Consumption	Reliability	Compatibility	Accuracy	Range	Programming	Total
Light Sensors	3	2	2	2	3	3	2	16
X-band Motion Detector	2	2	2	2	2	2	2	14
GPS Receiver w/ Antenna	1	2	3	2	3	3	2	16
Ultrasonic	2	2	2	2	2	2	2	17
Infrared	1	2	2	2	2	2	2	13

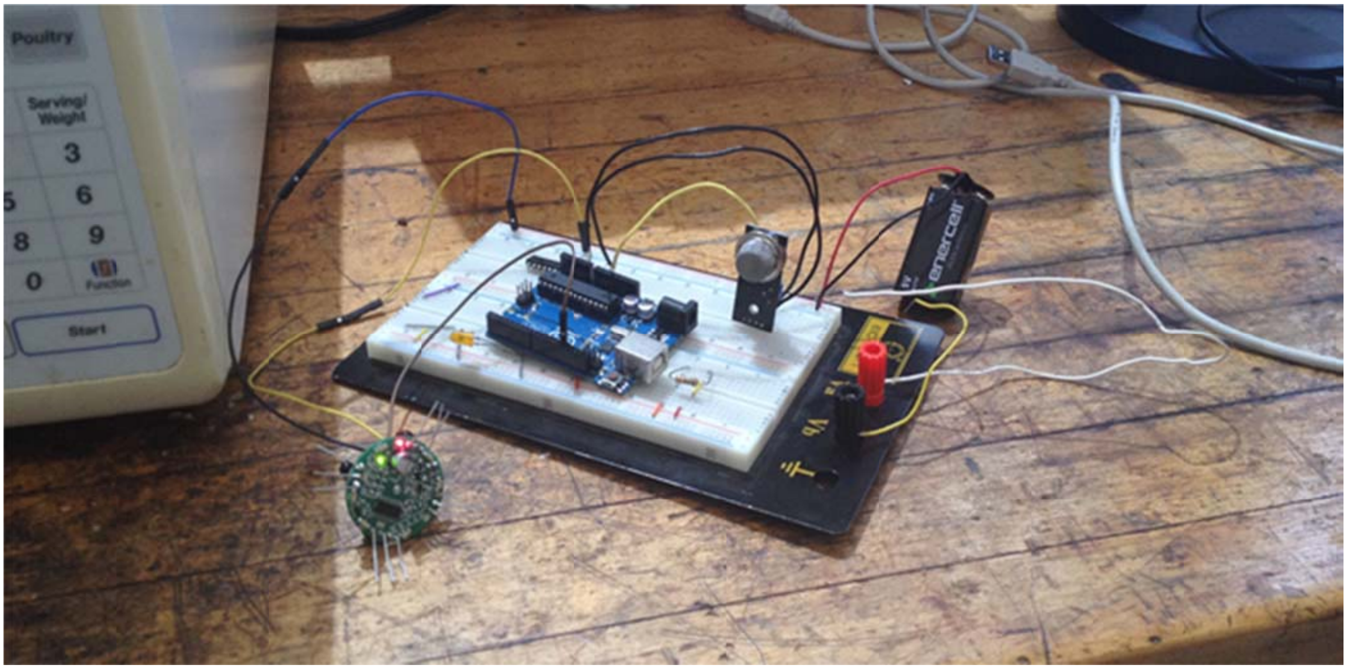
Implementation of the Top Design

The decision matrix helped in selecting the best parts for the mobile air-quality design. The PING ultrasonic sensor is used to detect obstacles up to 3 meters away from the base. This sensor has an output pin that is connected to the microcontroller which in turn calculates the distance an object is away from the mobile air purifier. Two 12VDC motors are connected to the uk1122 motor controller which, in turn, is also connected to the same microcontroller. The microcontroller sends signals to the motor controller that commands the motors to go forward, stop or spin opposite of each other. An IR transceiver is also seated on the mobile air purifier chassis, acting as a compass that will direct the base to a given air-quality sensor array. A 12V, 7amph battery supplies power to the motors.

The following image is of the completed robot chassis with all components mounted.

As for the air-quality sensor array, the MQ 135 gas sensor was chosen in the final implementation of the solution due to its ability to detect a wide range of problem gases including smoke, benzene and ammonia. The IR beacon on the air-quality sensor array matches the IR beacon on the mobile air purifier base. When the two IR beacons detect each other, the mobile air purifier will respond by traveling to the location of the air-quality sensor array.

The following image is of the completed air-quality sensor array with all components mounted.



The combination of air-quality sensor array and the mobile air purifier base is what makes the complete design of the mobile air purifier. With the air-quality sensor array, the base can sense the condition of the air in multiple rooms simultaneously.

The following image is of the completed robot chassis and air-quality sensor array.

Performance Analysis and Evaluation of the Project

Simulation/Experimental

The autonomously mobile air purifier has three main operating functions; that is, it detects contaminants in the air around it, moves autonomously through its environment and purifies the air. In order to accomplish these objectives and also meet the specifications laid out in the design of the device, a suite of tests will be developed and implemented. These tests will occur during different stages of the design's execution. Listed below are some of the tests that will be applied and expectations:

Parts test

Before any part or component is used in the execution of the design, it will be rigorously tested to make sure it functions properly. Each part is expected to work in compliance with its factory standard.

Obstruction sensing and rerouting test

The device senses obstructions a certain distance away from its surface. Once the device classifies something as an obstruction, it calculates another route to travel along.

Sensory test

The device sensed the level of contaminants in the air and then travels to that destination if possible.

Speed of mobility test

The device move at the speed specified in the design specifications.

Battery life test

The device function continuously at the battery life specified in the design specifications.

Evaluation against the design requirements

The system evaluation reaches the goal that we required and that fully automated and to do that we need a base with a motor, a motor controller, ultrasonic sensors, IR Beacons, and a Microprocessor. We plan to have this device locate activated air-quality sensor arrays installed around the home that read unclean air using gas sensors and dust sensors. The array will have its own beacon and microprocessor.

Conclusion

We believe that the device will have the highest efficiency in removing particles from the indoor environment. It will significantly reduce indoor air pollution and the ensuing haze risk if operated properly. The device will be cost-effective, not only in purchase, but also in maintenance (power, filter change, etc.). The mobility of the device will reduce indoor haze pollution in multiple rooms in the house/apartment setting. The most practical use of the purifier will be to reduce indoor pollution in one or two rooms only; most suitable, parents and children's sleeping rooms. The air purifier will spend most of the daytime in rooms during high outdoor pollution levels. For those living in an area with high background particle concentrations, as present in most metropolitan areas, this design will be recommended to permanently improve indoor quality.

Recommendations

For future iterations of this project, there are a few things we recommend. We recommend the following:

- Finding a way to implement multiple sensor arrays within the system.
- Adding a ring of ultrasonic sensors around the base so that the device has a better scope of vision.
- Replacing the motor controller that is only able to give a forward response with one that can give a reverse response.
- Installing proximity sensors to the system so that the device knows exactly how close it is to the air-quality sensor arrays.

By doing these changes, the true objective of providing clean air around the home will be achieved.

References

Works Cited

"How to use 315Mhz RF transmitter and receiver modules with arduino." *BUILD CIRCUIT*. N.p., n.d. Web. 23 Apr. 2014. <http://www.buildcircuit.com/how-to-use-rf-module-with-arduino/>.

"HowStuffWorks "How Air Purifiers Work"." *HowStuffWorks*. N.p., n.d. Web. 23 Apr. 2014. <http://home.howstuffworks.com/air-purifier.htm>.

"OreckÂ® AirInstinctÂ® 200." *Oreck*. N.p., n.d. Web. 23 Apr. 2014. <http://www.oreck.com/Oreck-AirInstinct-200-AirPurifier/544,default,pd.html?keycode=FH476>.

"PING))) Ultrasonic Distance Sensor." *Parallax Inc*. N.p., n.d. Web. 23 Apr. 2014. <http://www.parallax.com/product/28015>.

"Pololu IR Beacon Transceiver." *Pololu IR Beacon Transceiver*. N.p., n.d. Web. 23 Apr. 2014. <http://www.pololu.com/product/701>.

"REX-14D Round Robot Base w/ HP Encoders." *REX-14D Round Robot Base w/ HP Encoders*. N.p., n.d. Web. 23 Apr. 2014. <http://www.zagrosrobotics.com/shop/item.aspx?itemid=526>.

"airocideÂ® Better Air. Better Life.â„¢." *Airocide*. N.p., n.d. Web. 23 Apr. 2014. <https://www.airocide.com/>.

MLA formatting by BibMe.org.

Appendix

Arduino Mega 2560 Code

```
//Ultrasonic Sensor Input
int pingPin1 = 4;
//motor2
int FWB = 43;
int ENB = 41;
int BWB = 39;
//motor1
int FWA=35;
int ENA=33;
int BWA=31;
//IR Beacon Input
int IRN=13;
int IRS=12;
int IRE=11;
int IRW=10;
//Receiver Pair Input
void setup ()
{
 Serial.begin(9600);
 pinMode(ENA, OUTPUT);
 pinMode(FWA, OUTPUT);
 pinMode(BWA, OUTPUT);

 pinMode(ENB, OUTPUT);
 pinMode(FWB, OUTPUT);
 pinMode(BWB, OUTPUT);

 pinMode(IRN, INPUT);
 pinMode(IRS, INPUT);
 pinMode(IRE, INPUT);
 pinMode(IRW, INPUT);
}
//ultrasonic sensor distance result in inches
long inches1;
//desired distance that the base should stop away from an object
int stopping_distance = 20;
void loop()
{
 if(digitalRead(IRN) == LOW)
 {
  beacon_detected(IRN);
 }
 else if(digitalRead(IRS) == LOW)
 {
```

```
  beacon_detected(IRS);
 }
 else if(digitalRead(IRE) == LOW)
 {
  beacon_detected(IRE);
 }
  else if(digitalRead(IRW) == LOW)
 {
  beacon_detected(IRW);
 }
 else
 {
  loiter_algorithm();
 }
}

long PING_SIG(int pingPin)
{
 // The PING))) is triggered by a HIGH pulse of 2 or more microseconds.
 // Give a short LOW pulse beforehand to ensure a clean HIGH pulse:
 pinMode(pingPin, OUTPUT);
 digitalWrite(pingPin, LOW);
 delayMicroseconds(2);
 digitalWrite(pingPin, HIGH);
 delayMicroseconds(5);
 digitalWrite(pingPin, LOW);

 pinMode(pingPin, INPUT);
 long duration = pulseIn(pingPin, HIGH);
 // According to Parallax's datasheet for the PING))), there are
 // 73.746 microseconds per inch (i.e. sound travels at 1130 feet per
 // second).  This gives the distance travelled by the ping, outbound
 // and return, so we divide by 2 to get the distance of the obstacle.
 // See: http://www.parallax.com/dl/docs/prod/acc/28015-PING-v1.3.pdf
 delay(100);
 return duration / 74 / 2;
}

void loiter_algorithm()
{
 inches1 = PING_SIG(pingPin1);
 // N = NO MOVEMENT
 // P = BASE CAN PASS
 //CONDITION 1 -- N
 boolean condition1 = (inches1 <= stopping_distance);
  //CONDITION 2 -- P
 boolean condition2 = (inches1 > stopping_distance);
```

```
//N
if (condition1 == true)
{
  while(inches1 <= stopping_distance)
   {
    spin();
    inches1 = PING_SIG(pingPin1);
   }
   stop_now();
}
//P
else if (condition2 == true)
{
  while(inches1 > stopping_distance && digitalRead(IRN) == HIGH && digitalRead(IRS) == HIGH
&& digitalRead(IRE) == HIGH && digitalRead(IRW) == HIGH)
  {
     forward();
     inches1 = PING_SIG(pingPin1);
  }
 stop_now();
}else;
}

void beacon_detected(int Beacon)
{
 inches1 = PING_SIG(pingPin1);
 //if the north beacon is detected and the path isn't clear, loiter around
 if (Beacon == IRN && inches1 <= stopping_distance)
 {
   stop_now();
   loiter_algorithm();
 }
 //if north beacon is detected and the path is clear, go forward
 else if (Beacon == IRN && inches1 > stopping_distance)
 {
     inches1 = PING_SIG(pingPin1);
     while(inches1 > stopping_distance && digitalRead(IRN) == LOW)
     {
       forward();
       inches1 = PING_SIG(pingPin1);
     }
    stop_now();
 }
 else if (Beacon == IRS)
 {
   while (digitalRead(IRN) == HIGH && (digitalRead(IRS) == LOW||digitalRead(IRE) ==
LOW||digitalRead(IRW) == LOW))
    {
```

```
    spin();
   }
   inches1 = PING_SIG(pingPin1);
   while( inches1 > stopping_distance && digitalRead(IRN) == LOW)
   {
    forward();
     inches1 = PING_SIG(pingPin1);
   }
   stop_now();
  }
  else if (Beacon == IRE)
  {
  while (digitalRead(IRN)== HIGH && (digitalRead(IRS) == LOW||digitalRead(IRE) ==
LOW||digitalRead(IRW) == LOW))
  {
   spin();
  }
   inches1 = PING_SIG(pingPin1);
   while( inches1 > stopping_distance && digitalRead(IRN) == LOW)
   {
     forward();
     inches1 = PING_SIG(pingPin1);
   }
  stop_now();
  }
  else if (Beacon == IRW)
  {
  while (digitalRead(IRN)== HIGH && (digitalRead(IRS) == LOW||digitalRead(IRE) ==
LOW||digitalRead(IRW) == LOW))
  {
   spin();
  }
   inches1 = PING_SIG(pingPin1);
   while( inches1 > stopping_distance && digitalRead(IRN) == LOW)
   {
     forward();
     inches1 = PING_SIG(pingPin1);
   }
   stop_now();
  }
  else;
}
void forward()
{
 //left motor forward
     digitalWrite(ENB, HIGH);
     digitalWrite(FWB, HIGH);
     digitalWrite(BWB, LOW);
```

```
    //right motor forward
    digitalWrite(ENA, HIGH);
    digitalWrite(FWA, HIGH);
    digitalWrite(BWA, LOW);
}
void spin()
{
 //left motor forward
  digitalWrite(ENB, HIGH);
  digitalWrite(FWB, HIGH);
  digitalWrite(BWB, LOW);
  //right motor backward
  digitalWrite(ENA, HIGH);
  digitalWrite(FWA, LOW);
  digitalWrite(BWA, HIGH);
}
void stop_now()
{
 //left motor stop
  digitalWrite(ENB, HIGH);
  digitalWrite(BWB, HIGH);
  digitalWrite(FWB, HIGH);
  //right motor stop
  digitalWrite(ENA, HIGH);
  digitalWrite(FWA, HIGH);
  digitalWrite(BWA, HIGH);
}
```

Copy Of Final Proposal

HOWARD UNIVERSITY

Senior Design Final Proposal

Autonomously Mobile Air Purifier

Submitted by:

Raymond Jones
Warren Spencer
Kenneth Booker

Von Miles
Charles Brown

Table of Contents

Objective

This proposal is meant to present and give details on the development of our electronic design. The device will be able to move around on its own while filtering the air along the way. The aim is to improve upon the efficiency of air purification devices with the hopes that this project will be seen as something that could actually go on the market.

Introduction

There is an automatic vacuum that cleans the floor while being able to avoid, move around and go under certain obstacles. However, there is no air purifier like this on the market. Most air purifiers are stationary and generally oscillate from side to side just like a fan. There is a high chance that these air purifies are just filtering the available air in the room. Additional purifiers may have to be installed to filter the whole house depending on the size of the living space. The mobile purification device that we came up with is designed to hold and supply power to an existing purifier, but is also able to move around obstacles for maximum space efficiency and detect areas where air is densest.

Background

The air inside the home is generally dirtier than air outside since a house is a closed-off environment. Air purifiers are used to reduce the concentration of these airborne contaminants and can be useful for people who suffer from allergies and asthma. There are many types of air purifiers; the most commonly used are filter-based purification which traps airborne particles by size exclusion. Air is forced through a filter and the filter physically captures particles. Electronic air cleaners use an active electronically enhanced media to combine elements of both electronic air cleaners and passive mechanical filters designs. For those with allergies or asthma this poses a big problem. Forced air and heating systems only circulate dust particles and other pathogens around the house. Purifiers are devices that eliminate contaminants such as dust, pollen, pet dander and mold spores from the air, thereby creating a cleaner, safer environment. With the advancement in technology, the push for more advanced air purification units is being made but purifiers have not yet been autonomously mobile.

Problem Statement

Typical home air purifiers are generally stand-alone units which, by nature, have a restricted coverage area and their rated for maximum coverage area is based on a square room considering no obstructions to the airflow and no air contamination problems. Our air purifier will be able to detect the airflow patterns and the size and shape of a room while maneuvering around obstructions, all factors that affect coverage area.

Problem Formulation

I. Understanding Problem: Air pollutants are hazardous to those inhabiting the air space. EPA states that some toxic chemicals released in the air such as benzene or vinyl chloride are highly toxic and can cause cancer, birth defects, long term injury to the lungs, as well as brain and nerve damage. Each day, air pollution causes thousands of illnesses leading to lost days at work and school.

II. Identified Need: A system that is able to purify the air.

III. Research the Status of Art: Currently, in the market there are already high-tech air purifiers.

- Airocide
- Oreck Airstincts

Note: Observations showed that both air purification units are stationary and are limited to one room.

IV. Determine our Requirements: We want to further improve on the current air purifiers by making them able to detect air quality and move towards the source of corrupted air by using a wide range of transmitters, sensors, receivers, mobility kit, and a processor.

Status of Art

Air purification comes in many forms such as UV germicidal irradiation, activated carbon meshes, ionizers, and much more; however, none that was researched seemed to be mobile. So far all air purifiers on the market are stationary and it is interesting how this project's idea has not been implemented as of yet. Here are some examples of current stationary air purifiers:

Airocide—the harmful gasses emitted by products in the home (cleaning supplies, paints, even air fresheners) are concentrated in the purifier's densely packed matrix of highly reactive catalysts that destroy the pathogens on contact. Nothing captured, nothing cleaned.

Oreck AirInstinct 200—has a sensor that checks the particles in the air passing through it and automatically changes the airflow rate of the purifier.

Current System Drawback

Available air purification systems are all stationary and can only purify the air within a certain space. The air from around the house does circulate and will eventually reach the room that the air purifier is in; however, that may take a considerably long time. Air pollutants need to be removed from the air as soon as possible. One could place multiple air purifiers around the house but, taking into consideration the cost and energy needed to buy and supply those units with electricity, it may be inconvenient to some consumers. Therefore, to meet the needs of those consumers, we want to design one system with the ability to detect areas in the house or a building with the densest air pollution and move itself to the location to filter the air.

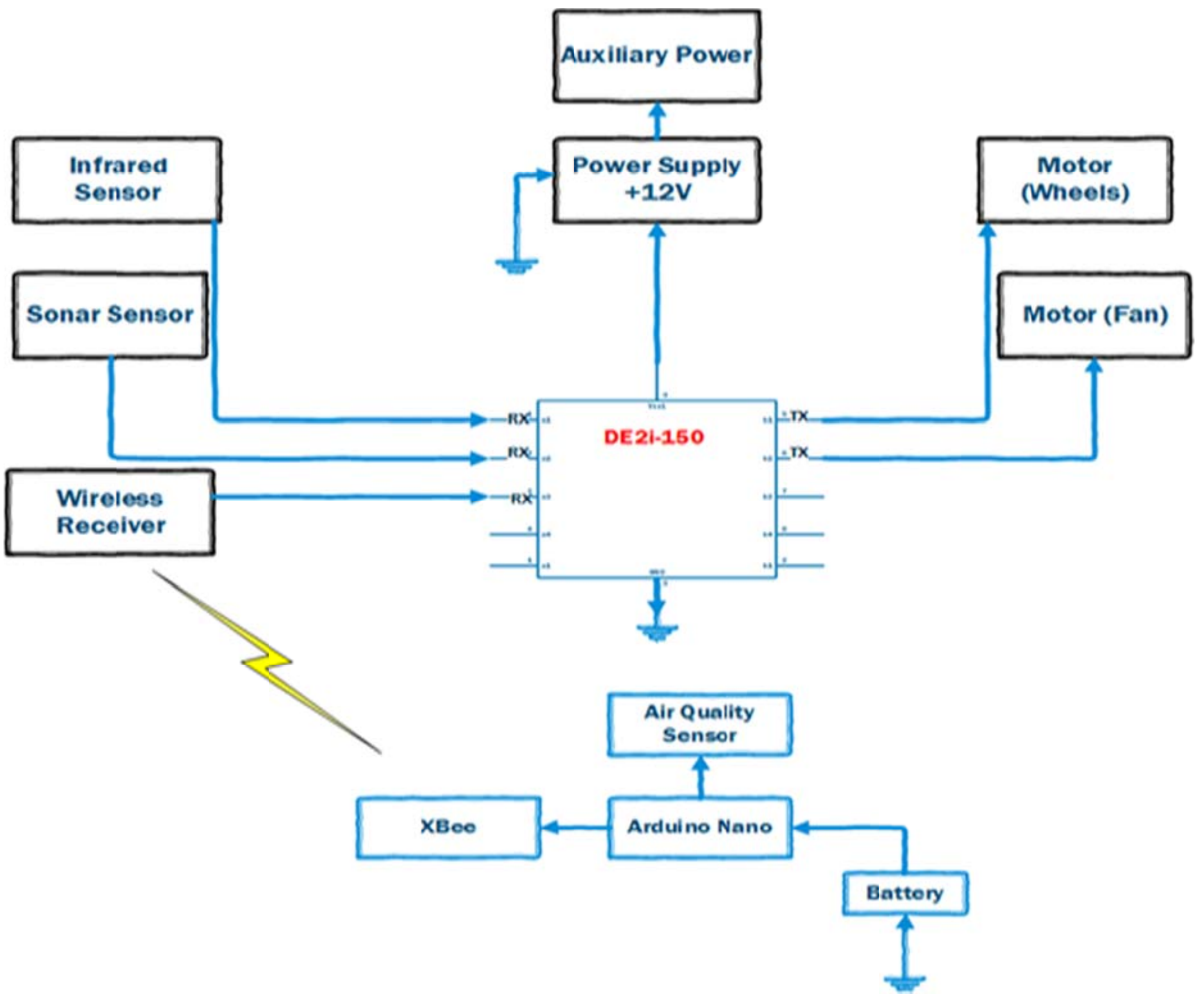
Engineering Approaches

The aim of our solution approach is to design a mobile device that will be able to avoid obstructions and ledges while navigating through any environment, whether it's an apartment space or a home. The device draws upon several inputs provided by an array of sensors which assist in the device's guidance ability and its ability to detect the quality of air in an environment. Multiple sensor arrays will be placed throughout a given area to sense air quality while the sensors that assist in the device's navigation will be placed directly on the device. The air quality sensor arrays will detect foul air and the device will attempt to navigate from its present location (point A) to the vicinity of whichever air quality sensor array detects the worst air quality (point B).

Initial Solution

There was no question that, in terms of choosing a processor to handle data retrieval and computing, our team would utilize the Intel De2i-150. This processor will be the focal point of our design. Our project also depends on using a combination of sensors to function effectively. Out of the thousands of sensors on the market today, we had to select the few that would best fit our project's goals. For our air quality sensor array, we wanted sensors that would detect bad air at a very accurate degree of precision. We also wanted our air quality sensor to be able to cover the scope of an entire room. Therefore, we decided to focus looking at the density of air in a given environment to help us determine the degree of air contamination. Density is a function of pressure and temperature. Air pressure is a characteristic that does not vary throughout an area so when foreign contaminants come and interfere with the expected air pressure or air temperature, the air density in the environment will change. The air pressure and air temperature values picked up by the air quality sensor arrays will be transmitted wirelessly to the De2i-150 which collects that data, compares it to the ideal air density and interprets the percentage error between the values to mean that the air has been contaminated by that extent. Furthermore, the mobile device will rely on an infrared sensor and an ultrasonic sensor to navigate. The infrared sensor will detect obstacles in the path of the mobile machine and the ultrasonic sensor will detect that the device may run into.

System diagram



Alternative Approaches/Components

As an alternative solution approach we considered using an actual air quality sensor instead of an array of sensors. This would decrease the topology and parts necessary for this network. In terms of air quality sensors, we looked at the SainSmart MQ135 Air Quality Sensor for Hazardous Gas Detection. However, after conducting more research into the product we realized that hazardous gas must be extremely close to the sensor for it to pick up on any deviation in air quality.

Required Knowledge and Course Work

For this project, we had to relearn some concepts from chemistry concerning density. We also have to attain a level of mastery of the De2i-150 which is the heart of our device. Also, knowing the concept of the Ideal Gas Law helped to narrow down the type of sensors we wanted to utilize. The ideal air density can be calculated using the equation below.

$$\rho_{ideal} = \frac{P_h}{R_{specific}T} = \frac{P_0 e^{-mgh/kT}}{R_{specific}T}$$

P_h is the pressure at a given altitude from sea level. In different parts of America, the value of P_h will vary. R-specific is a constant and T is the temperature measured by the temperature sensor. Once the ideal value for the air density is computed by the processor, the air density in the home is computed using the same general formula for density.

$$\rho_{home} = \frac{p}{R_{specific}T}$$

In the equation above p is the air pressure measured by a given air pressure sensor. T is the temperature measured by a given temperature sensor. Taking the percentage error of the two density values will tell the degree of air contamination at a given sensor array.

Feasibility of Design

This project is not an easy task if you were trying to build the air purifier from scratch because that's not our expertise. Our knowledge goes into building the mobile machine, which is not simple but has steps that can make the process go smoother. While using our intel atom board and sensors to program the machine where it can go throughout the area. The air purifier can just turn on and off when it needs to purify the area which, we will be able to do with the sensors and some rewiring with the intel atom board.

Goals

Our goals are to create an air filtration system that controls itself completely. Our hope with our air purifier is to increase upon the efficiency of most filtration units as set by the Department of Energy's standard for removing troublesome particles from the air. We are also working towards a device that moves around at a respectable speed, moving from problem area to problem area without much issue. Last but not least, we are attempting to set up a rechargeable system that is capable of detecting when it is low on power and moves back to its charging station in order to recharge it.

Design Requirements

Movement

The mobile machine is designed with four wheels and will be able to perform the following motion commands: forward, reverse, forward left, forward right, reverse left and reverse right. The autonomous air purifier's movement will be dictated according to the logic listed below:

1. If at any point in time the air purifier's battery life is below 10% then the air purifier will automatically attempt to return to its charging base if possible.

2. The air purifier is equipped with strategically placed sensors that continuously collect data from the environment around the device. The device uses the sensors to find a direction with no immediate obstacles/cliffs and then moves in the direction of that path.

3. If the device senses an obstacle or cliff a distance of 12 inches or less away and the obstacle/cliff is along the device's travel path then the device stops and waits 2 seconds.

4. If the device no longer senses the object after 2 seconds then the obstacle/cliff is considered non-stationary and the device will continue along its path.

a. If the device senses the object after 2 seconds then the device defines the path as a FAILED route and begins to store a temporary log of its FAILED paths, preventing the device from pursuing the same path again.

b. When attempting to change course, the limit on the distance that the device can approach an obstacle temporarily decreases from 12 inches to at most 2 inches.

c. The device then attempts to turn 45^0 clockwise then repeats steps 1 – 3.

i. If the device gets within 2 inches of an obstacle while attempting to turn then the device remains in its current location for ten minutes, resets its path log and then tries to find a new path.

d. If the device finds a free path then it returns to its default settings and continues moving forward.

i. If the device cannot find a new path after 4 iterations of step 4b then the device remains in its current location for ten minutes, resets its path log and then tries to find a new path.

Sensors

The system uses a few types of sensors to aid in its operation. Aboard the main unit, there are the ultrasonic sonar sensors and the infrared sensors. The sonar sensors are used to determine if there are any obstructions are in the traveling path of the unit by sending out an ultrasonic signal and checking the time it takes for the signal to return. The infrared sensors are used to edge detection so that the unit does not moving off the stairs and therefore would be placed on the underside of the unit.

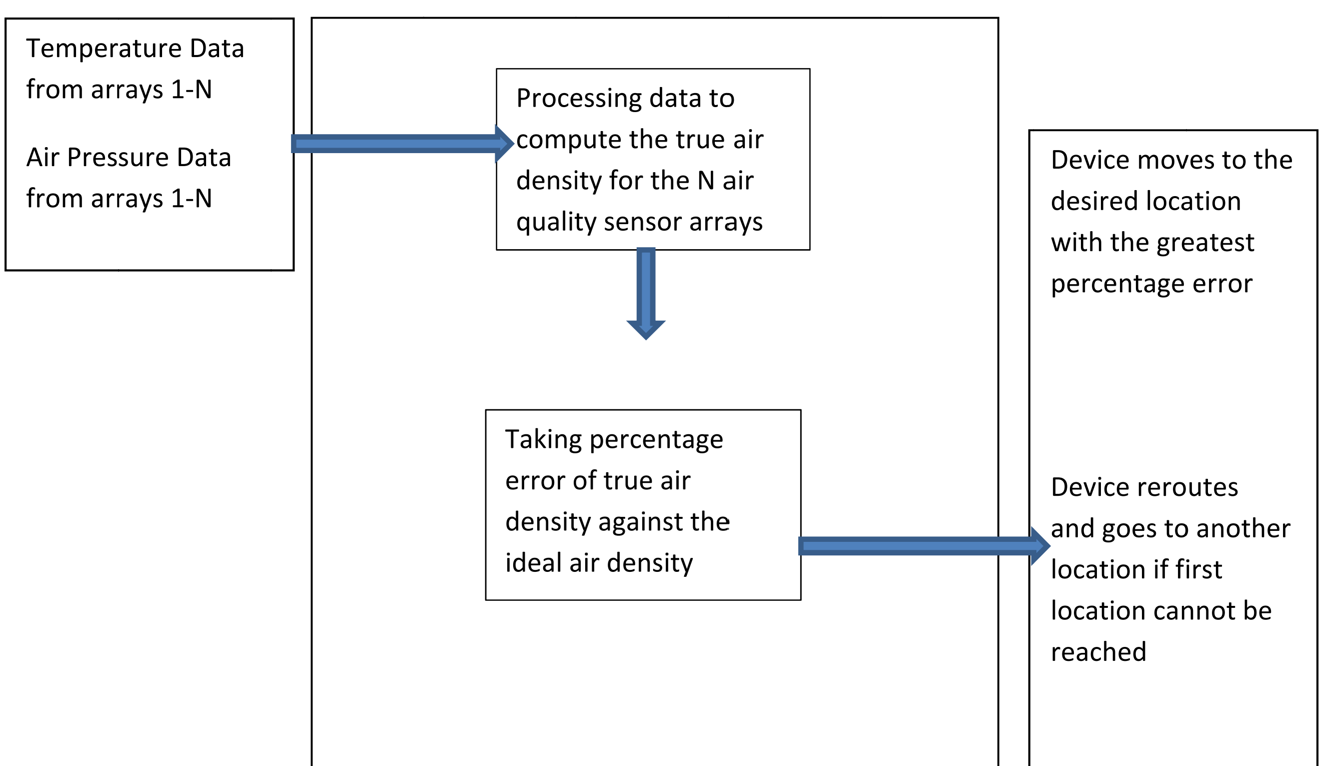
Purifier

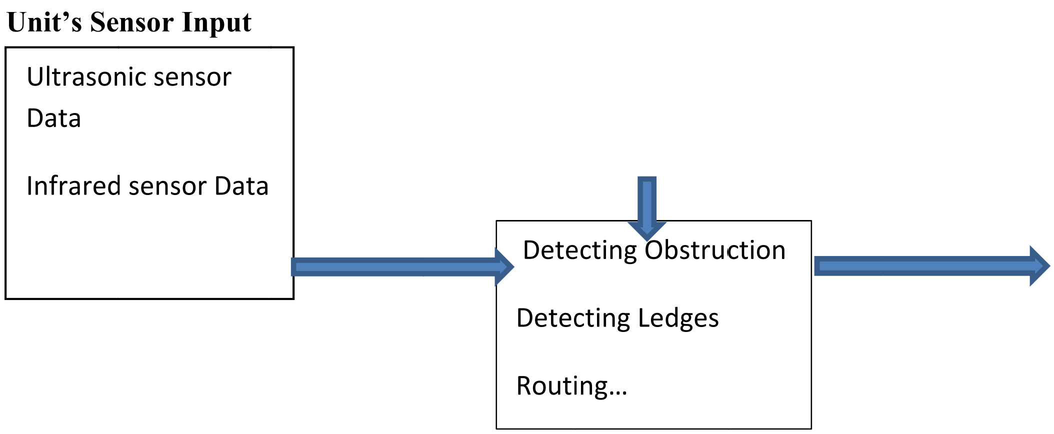
The purifier used will be absorbent and with the use of a vacuum it will take in air and absorb the air pollutants that pass through.

Air Quality Detection System

The smart grid unit will have a detection screen that displays the degree of air pollution with respect to the ideal level of good air quality. The detection screen will also display the battery level of the device periodically. There will be transmitters outfitted with barometers and thermometers around the house which will alert the mobile purifier that there is a change in air quality. The transmitter that measures the greatest deviation of standard air quality will be prioritized by the system, and it will head to the room where the transmitter is installed.

Sensor Array Input **Output**





Specifications

Mobility Speed	presumably 1.5 in/s need to be tested
Purifier Speed	-
Battery Life Expectancy	2 hrs. (if constantly operating)

Battery Type	Rechargeable 6-cell Lithium Ion Battery Pack
Wheel Diameter	3 in.
Wheel Width	1.18 in.
Base Measurement	9.36 in (length) x 9.09 in (width) x 2.82 in (height)
System weight	10-12 lbs.

Goal Requirements

Cost

In order to construct our autonomous air filtration unit, we need materials that should cost us a total of $300 (change this once you find a fan, stand, and battery unit).

Part Name	**Vendor**	**Unit Price**	**Quantity**	**Total Price**
Barometer	**eBay**	**$31.00**	**4**	**$124.00**

HC-SR04 Ultrasonic Module	**eBay**	**$3.99**	**4**	**$15.96**
TCRT5000L IR Infrared Reflective Sensor (2 pack)	**Banana Robotics**	**$0.99**	**1**	**$0.99**
4WD Drive Robot Chassis	**SainSmart**	**$45.99**	**1**	**$45.99**
Adsorbent Air Purifier		**$99.99**	**1**	**$99.99**
Thermometer	**eBay.com**	**$3.03**	**4**	**$12.12**
			Total	**$299.05**

Software

Since this unit shall be autonomous, we will have to construct a code using C as our main language in order for it to operate. There are three main concentration points that the code will be concentrating on: the sensing, the purifying, and the movement. The unit shall pan for any deficiencies in air quality and if it finds any, it shall move towards the general location and turn on the fan so that it may draw in air so that it may be pulled through the filters. The unit will be equipped with sensors so that it would be able to perform this tracking function, as well as navigate areas and avoiding edges.

Hardware

For this device, we require three different types of sensors. The first sensor, the air quality sensor, is the main component in making the system operational. This sensor will be used to check for impurity in the air and then assisting in the decision of when to turn the filtration unit on and off. The second type of sensor, the sonar sensor, is used for the purpose of mobility. The sonar emits a sound inaudible to the human ear and checks to see when the sound returns. By doing this, it determines the distance between the filtration unit and an obstruction that would inhibit its movement and therefore assists in knowing what direction to turn. The final sensor, the infrared reflective sensor, will be used to detect edges or, in this case, stairs. By producing a signal and waiting for it to return, the unit can tell whether or not it is near stairs and therefore know when to begin reversing.

We also have the base of the unit which contains wheels capable of 4-wheel drive. This way, the unit will have more free range of motion when moving around. In order to draw in the air for purification, we would require a fan and to purify the air, we would need a few filters. The system will be controlled through the use of an Arduino Mega microcontroller and the Intel Atom Board.

Testing and Verification Plan

The autonomously mobile air purifier has three main operating functions; that is, it detects contaminants in the air around it, moves autonomously through its environment and purifies the air. In order to accomplish these objectives and also meet the specifications laid out in the design of the device, a suite of tests will be developed and implemented. These tests will occur during different stages of the design's execution. Listed below are some of the tests that will be applied and expectations:

Parts test

Before any part or component is used in the execution of the design, it will be rigorously tested to make sure it functions properly. Each part is expected to work in compliance with its factory standard.

Obstruction sensing and rerouting test

The device is expected to sense obstructions a certain distance away from its surface. Once the device classifies something as an obstruction, it calculates another route to travel along.

Autonomous charging test

The device is expected to automatically return to a charging base when its battery life is 10% or below.

Sensory test

The device is expected to sense the level of contaminants in the air and then travel to that destination if possible.

Purification rate test

The device is expected to purify the air in the environment at the rate specified in the design specifications.

Speed of mobility test

The device is expected to move at the speed specified in the design specifications.

Battery life test

The device is expected to function continuously at the battery life specified in the design specifications.

Regulations

There are different regulations and standards we must abide by when we consider designing the actual hardware itself. For example the air purifier must remove 99.97% of 0.3 micrometer particles which is a standard for the air purifier we decided to use. Also the most standard household has a standard output of 15 to 20 amps (which you shouldn't exceed 80% of said amount) so we must stick to such standard when constructing the charger as well as any other power sources we will need.

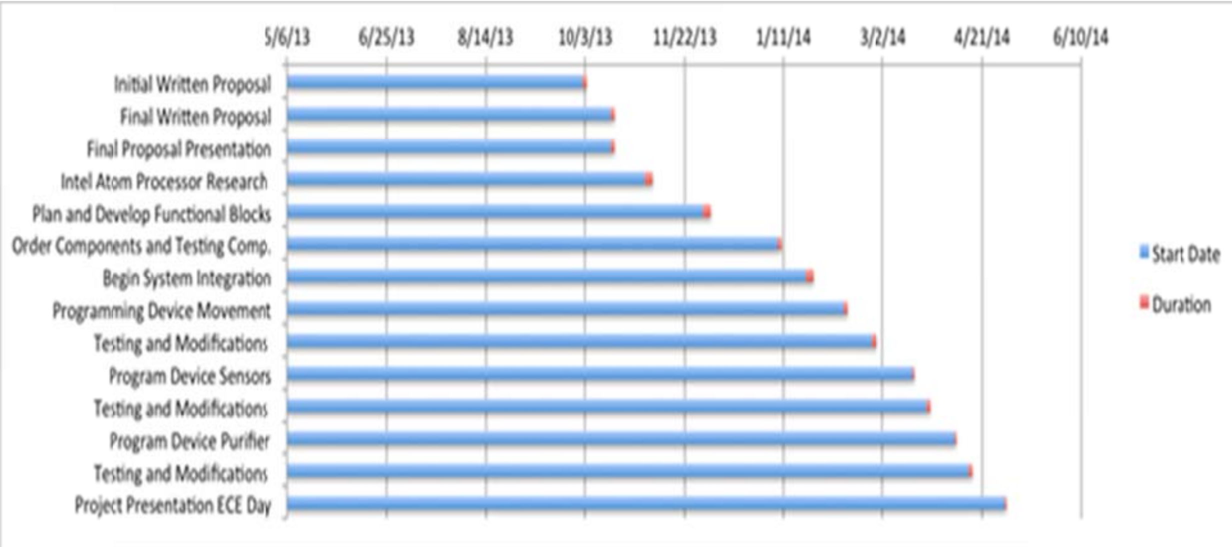
Project Management

Roles

Main Unit Programming and Remote Device Programming: Charles Brown and Von Miles

Hardware Design, Construction of Machine and Installation of Sensors: Warren Spencer, Raymond Jones and Kenneth Booker

Timeline



Deliverables

Once we have completed this project, we will have a main unit that can move around the house based on a signal that is being transmitted from one of our remote units and would begin to clean the air within that particular room before moving on to another room to repeat the process. As such, our unit will be able to discern between two or more results and prioritize the locations where it is needed the most. Our unit will be capable to navigate its way around the obstructions within its path with precision and accuracy. In addition, our remote units will be able to efficiently compute the air density of the room and transmit said result to the main unit.

Conclusion

We believe that the device will have the highest efficiency in removing particles from the indoor environment. It will significantly reduce indoor air pollution and the ensuing haze risk if operated properly. The device will be cost-effective, not only in purchase, but also in maintenance (power, filter change, etc.). The mobility of the device will reduce indoor haze pollution in multiple rooms in the house/apartment setting. The most practical use of the purifier will be to reduce indoor pollution in one or two rooms only; most suitable, parents and children's sleeping rooms. The air purifier will spend most of the daytime in rooms during high outdoor pollution levels. For those living in an area with high background particle concentrations, as present in most metropolitan areas, this design will be recommended to permanently improve indoor quality.

References

- http://home.howstuffworks.com/air-purifier.htm
- http://www.oreck.com/Oreck-AirInstinct-200-AirPurifier/544,default,pd.html?keycode=FH476
- https://www.airocide.com/
- https://www.epa.gov