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The Air Quality Smart Monitoring and Management System

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ABSTRACT

In this project, the problem that I attempt to solve is the lack of knowledge and action surrounding poor air quality. Originally inspired by a trip to India, I took action and built a prototype device that gave auditory and visual indications of the air quality and turned in an air ionizer as necessary. During project development, I interfaced a microcontroller with multiple peripheral devices, and I studied associated documentation as necessary. Using this knowledge, I wired each component to a digital or analog pin, and a ground power connection. Some components also required a 5 voltage connection. I then programmed my microcontroller to read the temperature, humidity, and pollutant ppm values from the associated sensors. During project development, I tested my device in five environments: my room, my backyard, an open garage with a car running, the air after a car runs, and a car running in a closed garage. I used this data to determine what pollutant ppm values constitute good, poor, and bad air quality. Using this information, I programmed the microcontroller to use LEDs and a buzzer to notify users of the current air quality conditions. Finally, I later incorporated an ionizer into the project, and programmed the system to switch it on when the air quality is bad. Through further testing, I was able to determine that each individual component did its job, allowing me to validate my device. Thus, this device could potentially make a difference for people in industrial countries facing respiratory diseases and can be applied to various fields of science.

Video Link

This is a link to a video I made that also explains the topics covered in this article:
https://drive.google.com/file/d/1hhbh25FO765AgvyfV6FfxuhSIj1JMcYn/view?resourcekey

Introduction (Background Research)

I was originally inspired by my 2023 India Trip, where I witnessed many people in severe medical condition due to lack of clean air and resources. India is an industrial country that suffers from pollution as actions have not been taken to help reduce pollution inputs, which hence made me think about other industrial countries suffering from similar problems. In 2019, air pollution was attributed to around 7 million deaths, with a majority being in the Indian subcontinent (NRDC). I recognized that climate change worsens air quality through "increased smoke from frequent fires, hotter temperatures increasing smog, and etc" (JEC Democrats). Thus, I was inspired to take action about this ongoing problem.

I researched some engineering projects that had been achieved by professionals and found that scientists are monitoring air quality through satellites. This served as inspiration for what I was going to do for my own device (NOAA). This project is important because it offers vital information to people in hazardous environments, telling them about the current air quality conditions and how to potentially improve them. If there is time, I hope to include a purifier that connects to the circuit. The criteria for this device is that if the air quality worsens, there needs to be an indication (and potential purification of the air) to the users to take action (assuming no purifier is involved). However, some constraints for this device is that it needs to be small and portable for users, while also being affordable to the majority of people, as this will likely be a necessity in the future.

The Engineering Solution, Prototype/Model to be tested

Here I plan to first build out a device where there is a sensor (the MQ-135) that detects various gasses (like ammonia, methane, and pm 2.5) and outputs information onto the the OLED Screen using an arduino. Then, based on the analog value read into the arduino from the air quality sensor, I thought of classifying the numerical ranges into a “good” and a “bad” category (maybe “poor” if time allows). I also want to connect the DHT-11 sensor as it tracks humidity and temperature; this is an important piece of info as it can help more accurately determine the air quality (ppm content) of a given area. Then, with help of the microcontroller - which also serves as a portable “powerhouse” of the entire circuit/project - I plan to play a sound on a connected buzzer if the Air-quality is above “poor” and I want to use 3 LED lights (one red, one orange, and one green) that corresponds to the current air quality reading. This system will visually and audibly inform users about the current air quality. With time and money being a bit of a constraint, this was the best I could do. However, if given more time and funding, I plan to add support to use a purifier that switches on whenever the air quality is “poor” or above - as a revised model.

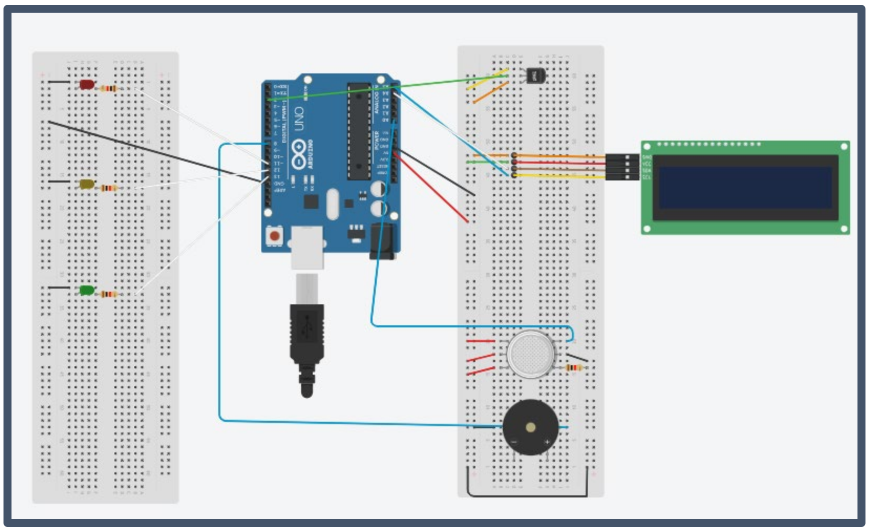

Figure 1. TinkerCad Diagram of Initial Device Prototype

Materials

Engineering Materials

- 1 Arduino Uno R3 Controller Board (Link)
    - Comes with a USB Cable that needs to be plugged in to a USB port
- 2 830 Tie-Points Breadboards (Link)
- 30 15-cm Breadboard Wires (Link)

- 8 15-cm Male-to-Female Dupont Wires (Link)
- 3 LEDs (Link)
  - 1 Red LED, 1 Green LED, 1 Yellow LED
- 1 0.95-cm 5-voltage Active Buzzer (Link)
- 1 2.44-cm OLED Screen (Link)
- 1 MQ-135 Air Quality Sensor (Link)
- 1 DHT11 Temperature and Humidity Module (Link)
- 1 Phone
  - To take pictures and help collect data
- 1 Computer w/ a USB Port
  - This is to upload the circuit into the Arduino IDE app

Revised Materials *Added on 11/24

- 1 IOT enclosed high-power relay (link)
- 1 Clarifon Ionizer (link)
- 1 Cardboard box to "shelter" this engineering project
  - Use scissors, tape, & a ruler to plan out the dimensions to adequately house the device

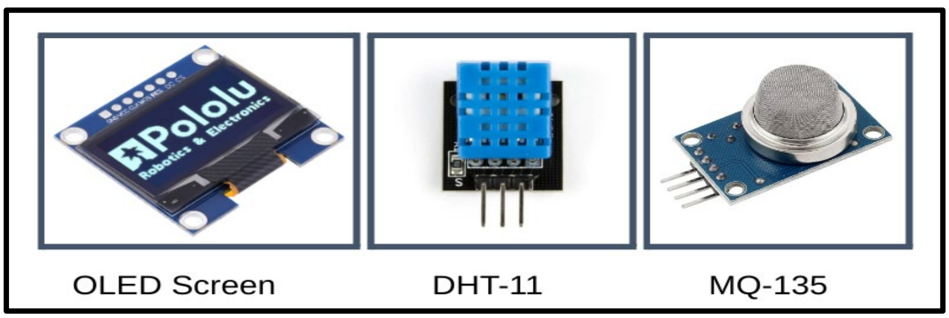

Figure 2. Pictures of Some Important Arduino Materials Necessary in this Project

Procedure

1. Understand how breadboards work and do a couple of practice tutorials on building circuits with breadboards
2. Study and read documentation regarding how the DHT11, MQ-135, OLED Screen, ***and IoT Relay work
3. Connect the power and ground supply of the breadboard to the microcontroller pins via jumper wires
   Use knowledge learned from sensor documentation to perform steps 4-5, and 8
4. Connect the DHT11 and MQ-135 to the the microcontroller via jumper wires
5. Connect the OLED Screen to the microcontroller via male-to-female jumper wires
6. Connect the Passive buzzer from the breadboard between ground and a digital pin on the microcontroller
7. Repeat step 4 to connect the 3 LED Lights (use a separate breadboard if running out of space); Connect

resistors in series to limit the flow of current through the LED and its digital connection(s) on the microcontroller

8. ***Connect the IoT Relay to a digital pin and ground connection via jumper wires, then plug the ionizer into one of the relay's outlets
9. Connect the Microcontroller to and IDE in computer via a USB Cable/port
10. In an IDE (preferably Arduino), write code that satisfies the following concepts:
    a. read from MQ135 and DHT11, then use info from these sensors to output to OLED
    b. turn LEDs, buzzer, purifier on to keep air quality good and notify user the current air quality
11. Switch on the Serial monitor once finishing the code and upload it to your arduino circuit board

*** added on 11/23/2023

Results - Data/Observations

Table 1. Data Table

	Trial 1 (PPM)	Trial 2 (PPM)	Trial 3 (PPM)	Average (PPM)	Standard Deviation
My Bedroom	8.83	6.74	8.52	8.03	0.92
Backyard	5.58	4.14	6.91	5.54	1.13
Open Garage w/ Car Running	33.54	50.83	42.05	42.15	7.06
Air after Car Runs in an Open Garage	21.05	23.95	22.66	22.55	1.19
Closed Garage w/ Car Running	90.12	106.72	100.94	99.26	6.88

I collected data by using the MQ-135 to generate readings on to my OLED Screen based on different environments. The bottom environments were meant to represent the poor to bad air quality range, while the top 2 were meant to represent the good air quality range. I noticed that the sensor will initially detect high readings at first, but then stabilizes and gives me the correct readings. I notice that the MQ-135 gets hot each time I activate it and has a distinct odor. I also included standard deviations of each environment.

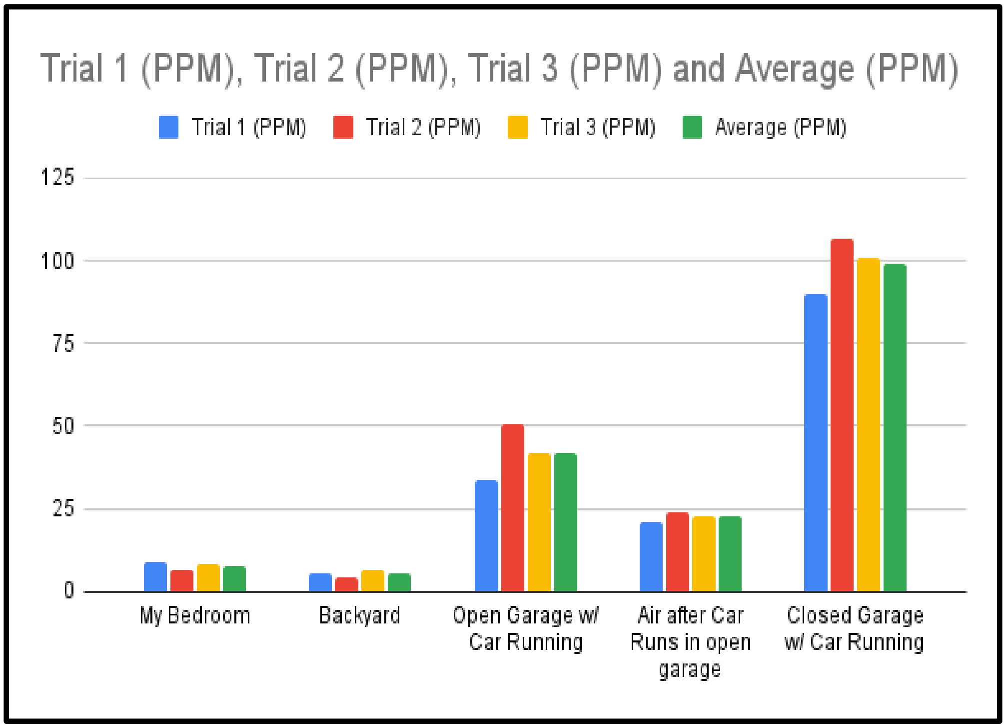

Figure 3. Bar Graph of Data Table (Figure 2)

In the table above, I created thresholds that defined what I considered to be good, poor, bad, and etc. Based on this, I checked if the device's visual and audible notifications worked, which they did. I also wanted to make sure that the ionizer was doing its job by helping to purify the air. To verify this, I checked the PPM in my two "bad" air environments, and with the revised code, the ionizer automatically switched on. I checked if the air quality got better, and once again it did. This is proof that my device works and can be a tool for people facing poor air quality.

Table 2. Data Collected After Revision + Qualitative Data Chart/Table

	Collected PPM	Category	LED Light	Buzzer	Ionizer	PPM After Ionizer Is On
My Bedroom	9.53	Good	Green	Off	Off	N/A
Backyard	7.37	Good	Green	Off	Off	N/A
Open Garage w/ Car Running	46.86	Bad	Red	On	On	25.61
Air after car runs in an open garage	23.59	Poor	Yellow	Off	Off	N/A
Closed Garage	112.51	Severely Bad	Red	On	On	71.19

w/ Car Running						

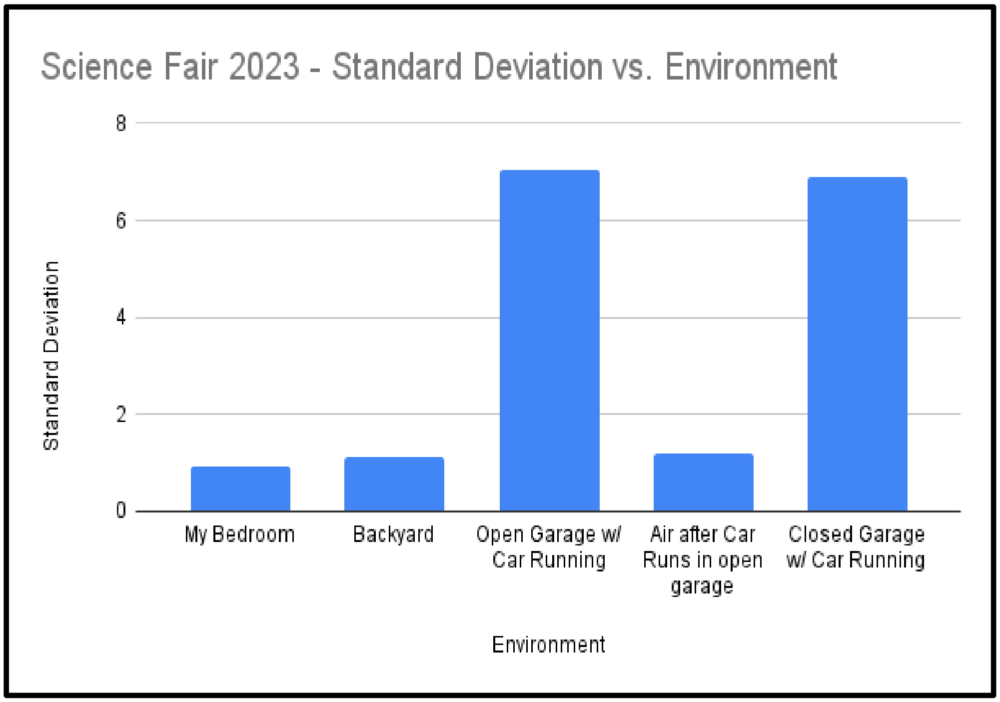

Figure 4. Bar Graph with Standard Deviation

Revised Solution and Prototype/Model

Figure 5. Revised Prototype (with Ionizer) and Code with added thresholds

After realizing that the way I was using the MQ-135 worked wasn't compatible with the data collection process of the science fair guidelines, I realized that I needed to change how I was interpreting the data sent from it. The sensor uses the noxious gasses in the air to increase the output resistance, which causes a decrease in the analog voltage read by the Arduino. However, I realized this was a flawed method because it gives no info about actual pollutant ppm values in the air. So, I changed the code to utilize an MQ135 library that would calculate the total pollutant ppm from the raw analog signal. While it would've been better to read the PPM of specific gasses, I figured that this would do for now. Based on the ppm data I got on the previous slide, I was able to go back to my original code and change the conditional logic to be based on ppm values instead of the raw output voltage from the MQ135, and was able to adjust the thresholds accordingly. My thresholds are: Below 20 ppm is good, 20-40 is poor, 40-60 is pretty bad, and above 60 is severely bad. Based on these new thresholds, I was able to make certain LED Lights flash and play the buzzer if appropriate. My next big revision was adding an ionizer. Before, I mentioned wanting to add a purifier, but since all purifiers come with a remote or button switch, I needed to get an ionizer that would immediately switch on once plugged into an outlet. Once I got an ionizer, I plugged it into the IoT relay that I ordered, and wrote code to switch it on when I read a ppm threshold that fell into the "Bad" air quality category. Then I collected qualitative data to see if my device worked at the appropriate times and recorded it on a spreadsheet located on THE PREVIOUS SLIDE. I also collected data to see if the ionizer was actually making a difference in the air. Those results are found on the previous slide where I have all my data collection.

Discussion

Statistical

Environment 1: Here I calculated the average of this environment to be 8.03. This means that one should expect to get around 8.03 ppm overall if tested inside the room. While this won't be too similar due to different conditions in each room, one should still expect to get similar conditions. I calculated the standard deviation of my data, which was about 0.92. This means that 68% of the ppm values should be less than or equal to 8.95, 95% of the ppm values received should be less than or equal to 9.87, and 99.7% of the ppm values should be less than or equal to 10.79.

Environment 2: For this environment, the average I calculated was about 5.54 ppm overall. This means that I should expect to get around 5.54 ppm if testing in my backyard with similar conditions. It isn't feasible for everyone to get the same results as the temp, humidity, wind, and time of the day may change. I calculated the standard deviation, which was around 1.13. This means that 68% of the ppm values in this environment should be less than or equal to 6.67, 95% of the ppm values should be less than or equal to 7.80, and 99.7% of the ppm values received should be less than or equal to 8.93.

Environment 3: In this third environment, the average I got was 42.15. This means that I should expect to get around 42.15 ppm if testing again in an open garage with my car running. People doing a similar experiment may get different results as the ppm in the car may fluctuate, but should be distinctly similar. I calculated the standard deviation, which was around 7.06. This means that 68% of the ppm values in this environment should be less than or equal to 49.21, 95% of the ppm values should be less than or equal to 56.27, and 99.7% of the received oom values should be less than or equal to 62.33.

Environment 4: In this environment, the average I got was 22.55. This means that I should expect to get about 22.55 ppm if testing the air again after a car runs in an open garage. People doing similar tests may get different results as there are different factors that could manipulate the air. I calculated the standard deviation, which was around 1.19. This means that 68% of the received ppm values is less than or equal 23.74, 95% of the ppm values is less than or equal to 24.93, and 99.7% of the ppm values is less than or equal to 26.12.

Environment 5: Here, the average I got was 99.26. This means that I should expect to get about 99.26 ppm if testing again in a closed garage with a car running. People doing similar tests may get distinctly similar results as cars pump different levels of gasses. I calculated the standard deviation, which was around 6.88. This means that 68% of the ppm values is less than or equal 106.14, 95% of the ppm values is less than or equal to 113.02, & 99.7% of the ppm values is less than or equal to 119.9

Verbal

I noticed how outside environments that had outside air involved had relatively smaller pollutant ppm values. This means that outside air is more pure and is probably a more ideal environment. However there is no wind or drought to affect the ppm in the air, so this base air can be best attributed as the “good” air to breathe in. A pattern that I noticed was that the longer the device was left on, the more accurate and sensible readings it provides. Upon initial use, the sensor gave some high values of ppm, but then quickly stabilized to the correct ppm of the given environment, which was the only error that I found during my data collection. Some variables that would have influenced my results were definitely temperature and humidity, as the ppm I used was a collective ppm that took into account temperature and humidity as detected by the DHT-11. Another factor could’ve been wind, as if there was more wind in the outside air, then more dust particles would be mixed in with the air and the sensor would likely read higher ppm values of noxious gasses. The final important variable was the time of the day I set it in, since human activities that pollute the air occur more oftenly is daylight. Thus, I would likely get higher ppm values for outside air during the day. Inversely, during the night, I could get lower ppm readings as there would be less human activity involved. These ideas, however, don’t apply to the simulated environments that I tested.

My prototype is an improvement over what’s available because it is very, very successful in communicating the users of poor air quality and offers a contemporary solution that helps to stabilize the air quality until the users have made a call to action. While there are a few small issues with my device, like some abnormal readings when first switched on, I think my device still generally serves its purpose and gives users a clear vision about the air quality in their houses and how to stabilize it for some time until a bigger call to action can be formed. This is critical in industrialized places where pollutant ppm could constantly be high in the air without citizens realizing it. At the end of the day, I believe my project turned out the way I expected, giving me the results that I hypothesized before starting on the project. This is useful for construction as they can take measures to ensure that all people are breathing decent air.

Conclusion

What was the Solution that Solved your Problem?

My project mostly solved the problem of lack of proper monitoring of air quality as there are many components - an OLED Screen, Flashing LED Lights, and a Buzzer that notify the user of good or bad air quality. My project also focused on the management aspect as well, as I was able to plug in an ionizer that switches on everytime the air quality becomes worse. This however, serves more as a call to action and is a temporary resource for the users so that they know that the air quality is worsening and hopefully take the appropriate measures to stay safe and healthy.

Were You Able to Scientifically Explain Why You Got the Results That You Did?

I got my results because I was tracking an increase in ppm with and without outside air. For example, there was less pollutant ppm in an environment with a running car and open garage than in one with a running car and a closed garage since the PPMs were able to escape to the outside space. In a closed environment with a running car, there is no outside air interfering with the PPM, so my sensor tracks just the PPM produced from the car, meaning I'll get a higher number.

What Application(S), If Any, Do You See for Your Work?

My work can be used for fire detection, as fires create noxious gasses that pollute the air. It is also useful for the medical field, as researchers can look at my data and see how they can come up with ways to improve quality of life at home based on the noxious gasses that are being read by my monitor. My device could be built into a room or structure (like a parking garage) or it can be a portable unit that can be wheeled into a room if one wants to take PPM measurements.

Do You Have Any Further Research Questions or Other Variables to Test as A Result of This Project?

As I have mentioned, I want to test how these noxious gasses are impacting our lungs when we breathe them I also want to test something more specific, like the PPM of a specific pollutant such as Carbon Monoxide. This is so that I would have a specific threshold that I can gather data from

Reflection/Application

Throughout this project, I learned how important preparation is since without a clear vision about how you are going to approach all aspects, I realized that I was in a mess and faced a lot of complications. If I were given more time, I would've actually thought about the sensor I got and would've preferably ordered an MQ-7, which tracks Carbon monoxide. This is so that I have a clear threshold as to what I am tracking as I now only can find the air quality number from the MQ-135 based on the ppm from numerous noxious gasses combined. If I also had more time, I would have liked to solder and house my project nicely to look professional. I also wanted to be able to go to more places and collect data about each individual air quality if I had the time, so I can get real, authentic data rather than having to simulate certain environments.

In this project, I learned a lot on how to be determined and never give up, as many things did not go right through this project, but I eventually overcame those challenges with a growth mindset. My next steps for researching this problem is to counteract the lung diseases that come from poor air quality as that is the incentive and selling-point for my project: how to help people remain healthy. I also realize that what I have built is just a prototype to my true vision of it being soldered and housed in a nice way, but I wasn't able to achieve those goals due to the time constraint that I faced. My results from this product serves as a stark reminder of the global impacts that we are committing and thus also serves as a call to action for users to be careful to not continue polluting the air. They can also apply into environmental science as researchers continue to study the causes and effects of global warming, and can help design new solutions that avoid spreading toxins and other particles in the air.

Acknowledgments

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I have achieved in this project. The next person is Cyril Empig, who helped me with planning and strategizing my research. Finally, I would like to thank my science teacher, Megan Stuart, who gave me a clear idea on the specific parameters of my research and how I can be successful in this project with the time I was given.

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