Air Quality Brick

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***Abstract*— This paper will overview the thought process and design concepts used to create a citizen air quality sensor system that is capable of providing air quality data on a local scale. This paper will also discuss why understanding the air contamination in a local area is important as well as the reasoning behind these concerns. These concerns form the problem that is to be solved which is a general hazard to health or the environment with a side-benefit of understanding an area's atmospheric composition easier and better.**

***Keywords*— Cost-Effective, Replicable, Community Based, Pollutants, Accessible, Modular**

I. INTRODUCTION

Pollution is a matter that seems to never get fully recognized by our society. Air pollution at high levels can cause a variety of adverse health risks. Some examples include heart disease and lung cancer [1]. Even with knowing this, most people don't look into how pollution affects them in their community. Our goal is to allow people the option to see what pollutants affect them in their communities. The objective is to create an easy to use, solar-powered, modular system that uses multiple sensors to gather data on different pollutants. The data will be easily accessible online for users to decide how to combat pollution in their community.

II. FORMULATING THE PROBLEM

The modern world has sometimes experienced unhealthy or even deadly levels of pollutants in the very air humans breathe [2]. Finding local information on air quality is based on algorithmic guessing [3]. There are plenty of resources to make guesses, but true measurements of air quality are difficult to come by despite the technology existing in some forms. Services such as the weather apps on phones and PC's give information about air quality and primary pollutants, however this is based on an average of sensors placed around a large area such as a county [4]. For a single person or community attempting to gain information from a specific location and those who would like only to gain information about certain pollutants that may not be commonly measured, this will not do the job. The obstacle for local measurements of very customized intakes is that the technology may exist, but it is not compiled to fulfill this need.

A. BACKGROUND INFORMATION

Before reading further into the proposed device and related information, a quick background check is provided here on: air quality sensors themselves, effects of contaminated air, how common values are obtained.

First, air quality sensors are devices used to detect levels of contamination in the air [5]. The inner workings of air sensors vary widely from lasers that measure size and number of pollutants to ultrasonic disruption when sending out sound waves to bounce off pollutants [6]. The sensors take their measurements and then convert them to an electrical signal regardless of the method the data was gathered. It is here where the proposed device comes into play to read in this electrical signal to convert it into an easier to read format. So, knowing how the sensor functions is important but for the interest of the project, the conversion and formatting is the focus.

Second, air contamination refers to chemicals or particles in the air that can harm the health of humans, animals, or plants [7]. There is no specific measure to account for as the project calls for a variety of measurements to be available. Knowing this, there are a great many health concerns that could be revealed when testing the air quality. From the National Geographic team, “Long-term health effects from air pollution include heart disease, lung cancer, and respiratory diseases such as emphysema. Air pollution can also cause long-term damage to people's nerves, brain, kidneys, liver, and other organs. Some scientists suspect air pollutants cause birth defects” [8]. If the proposed device can reveal these pollutants in local communities, many could be saved from undesirable health risks or even death.

Third and lastly, the U.S. government and some companies provide information on air quality regarding an area through weather apps. These apps source their information from sensors placed around the region being tested. These sensors are placed in general locations and then use algorithms to average and guess air quality of regions in between the sensors [9]. Think of it like a wide web with gaps between the strings that are filled in after the web is made. For general use, this is fine, however for someone wanting to use the real data in their research, this will not do. Having access to the true air quality data would allow for a more accurate groundwork for any point trying to be proven. This is whether to prove the air quality around a certain area is harmful or that the common values are misleading, whatever the case.

Some people may realize that they can receive information on the air quality around them through a weather app on their phone. The device to be created will acquire data for specific pollutants that may be detected within its area. It will then output its receiving data to a database online and upload how much of the specified pollutant is present. The difference with a weather app and our air quality device is that the app gets its data from the sensors across the country. Then, the app averages the values depending on where the phone may be located. The air quality device will receive real present data for pollutants at its location and will be displayed in real time onto a website for a specified user.

There are various types of pollutants within our own environment. In the area of Cookeville, the AQI (Air Quality Index) is on average 40. Therefore, the most present pollutant in the area is PM2.5. One of the pollutants that will be measured and will have a dedicated sensor is pollutant PM2.5. An air quality sensor should be able to detect all types of PM pollutants within the area and give a statistical number representing how dense the population of the pollutant is present.

B. SPECIFICATIONS AND CONSTRAINTS

Here are the “shall statements” of the project. The specification and constraints placed upon the construction and design of the project were given by the customer and also based upon some background research.

- Shall be protected against rain. The standard to be followed will be IPX4 water resistance from all directions to protect against rain. Nominal to heavy rainfall will be accounted for, but standard IPX5 protection against low pressure jet streams are not guaranteed.

- Shall be protected against dust and small objects. The standard to be followed will be IP3X which states protection against hazardous parts, thick wires, or solids of sizes greater than 2.5 mm.

- Shall be modular. In this instance, modularity refers to the ability to change to a multitude of previously tested and approved sensors without the need to change any or at most 2 select settings. The change of sensor should be seamless and handled by the board and software.

- Shall have a selection of tested and approved sensors to cover a range of pollutants, particulates, air composites, and other qualities. These sensors should all share the same interfacing port and work independently from another.

- Shall be relatively cost-effective. The device, additional components, and software should remain under $100. The cost for sensors is not taken into account as the sensors are used on a case by case basis.

- Shall be easily replicable. The device and additional components shall be mostly, if not entirely, off the shelf purchases. This should lower the technical knowledge required to construct the device tremendously. The software should be available for free online.

- Shall be able to operate with 3-5 sensors sampling independently of each other. Sensors will take samples at set intervals and be read and stored onto the device periodically. Samples may be read and written one at a time.

- Shall be well documented. All questions cannot possibly be answered, however, a very strong groundwork for how the device operates and basic functions with limitations shall be documented. This should answer common questions that may arise. More specific questions would require additional testing.

- Shall have easily accessible data. The device should be able to take data from storage and send it to a website to be read from the user remotely. If the user wishes, he/she may also read data from the device directly. Formatting will be basic and leave room for improvement for future development.

- Shall utilize sensors that share the same type of I/O port. The sensors should be able to be interchangeable to any other sensor port on the device. To achieve this, the sensors all use the same I/O and similar data transfer options.

These are the specifications to be met when constructing and designing the project. They are absolute statements. It should be noted however, that given the status of the team as undergraduate students, the project may falter in regards to certain projections i.e. knowledge, time, and resources.. Realistic goals are at present set, but, due to the unpredictability of the future, these goals may change.

C. SURVEYING SOLUTIONS

Before a settlement is made on an approach to success, existing methods are taken into consideration. The reason for this is simple: if the solution already exists, then this project is folly. However, given the solution is absent from the known world, this allows for a multitude of perspectives from previous works when looking for a solution to call original. What was found: air sensors are not typically used in an interchangeable way but other sensors are, some multi-use air sensors have been made but have limitations, modular microcontrollers can be used to fulfill the project needs when modified, and air quality checks are public information given by companies.

First, the technology of today already includes a large variety of air quality sensors. The issue with these sensors is their inherent simplicity. One sensor can be used for its particular task, but if the user wanted to use air sensors, these could not be interchanged. The housing unit, or chunk of material the sensor is attached to, will never change or work for another kind of air sensor. This is one issue that needs to be addressed. A core goal for the project is to allow for interchangeable air sensors. This means that the housing unit must accept many different types of air sensors. The technology to do this exists, but it has not been compiled together in this way. For example, the company Ellab makes vacuum, pressure, and temperature sensors that all use the same connections and may therefore be used interchangeably [10]. Their methods may be incorporated for subverting this issue.

Another solution from today sees that air sensors already exist with the ability to measure a range of pollutants, particulates, or compositions in the air. The company Airly Inc. produces a device called Airly PM. [11]. This device is capable of measuring many pollutants and particulate matter all in one easy to use device. So, multiple kinds of sensors can be used simultaneously on one device, however, this device comes with a preset of sensors that cannot be altered or customized. If the user wanted to measure something not included in the preset, this would not be possible. This was likely to stay in the realm of “easy to use”. Finding a balance of easy to use and having a variety of sensors is one target for the project. More options could inadvertently confound the user and should be avoided.

Other works to consider are Arduino and Raspberry Pi which are popular microcontroller boards that allow for modularity[12] [13]. The problem inherently requires modular components, so the existence of these boards does allow for an off the shelf option. This allows for a more simple user experience which ultimately does make the product more accessible to more people. Lowering the knowledge requirement for constructing this device potentially allows more to be built and hopefully improved for future use around the world. The concept of this device being easy to make, easy to use, and give sufficient data is a driving factor when making a community-friendly product.

One last piece of existing works to consider is the air quality sensors providing regional information for large portions of the world. A big example is the Air Quality Index (AQI) provided by the U.S. Environmental Protection Agency. The AQI takes information from sensors placed in key locations around the United States to make assumptions about the air quality for a certain area using sophisticated algorithms [14]. This may sound like the problem is already solved in this case, but this project seeks to get true local results. The algorithms used can only make guesses. Bypassing the algorithms and jumping straight to the raw data will provide a true local reading for the air quality around a designated region.

III. LOOKING FOR SOLUTIONS

The goals specified are to be achieved within our detailed window of time. During that period, the design process and phases may contain obstacles that could potentially slow development and cause other problems if not solved. Predicting and being prepared for those potential obstacles gives more options and further development to meet specifications and requirements.

As stated before, the task of having a port designed as input to use a desired sensor interchangeably is difficult to solve. Finding an adapter that can be integrated into the system can solve this issue. Since there are many different pollutants, one goal is to make the air quality device to house 3 different pollutants and receive informative data on each at the same time. Even though it will be able to send current-time data for 3 pollutants, the device shall be able to house sensors for 8 pollutants in total.

Another potential issue that may hinder the replicability is using custom components within the device in order to achieve requirements. It has already been stated that one goal is for the air quality sensor to be easily rebuildable and low cost. Therefore, custom products that may be difficult to remake or design are not to be used during the development of this project. Arduinio or Raspberry Pi products can solve interface issues and system user control. Microcontrollers that can communicate using SPI, I2C, or UART to other receiving microcontrollers can be useful for the functionality of this device.

A. UNKNOWNS, IMPLICITS, EXPERIMENTATION

Accounting for the future and all hindrances that may follow it is, to put it bluntly, currently not feasible. The best that can be done is predicting likely hurdles and how to approach them.

1) The team falls behind on deadlines.
    a) In this case, the team should begin to reassess what can be done in reasonable time and double efforts on this.
2) There are difficulties with the microcontroller boards.
    a) In this case, the team should do plentiful research on the board to investigate workarounds or modifications. If this does not solve the issue, then another board will have to be chosen.
3) The board is unable to handle wireless communications to the Internet.
    a) In this case, the board will need to be altered to accommodate network functionality.
4) Certain sensors are malfunctioning with the device.
    a) In this case, the sensors that are malfunctioning will need to be discarded in favor of an alternative.
5) The necessary knowledge to complete a task is unknown to each team member.
    a) A team member will volunteer or be selected to investigate the problem and research the necessary knowledge to complete the task.
6) A team member is inhibited from completing designated workload.
    a) Other members of the team will divide the designated workload amongst each other.

Again, predicting the future takes into calculation far more variables than the average human is capable of working with. Knowing this, there are things that can be done to minimize the risk of failure: consistent updates from members, asking for help when it is needed, seeking outside knowledge, performing thorough research, allowing time for sufficient experimentation, and designating one member to allot time for tasks.

During experimentation, the goal should be to find the most effective design regarding costs, effort in construction, and completion following the measures of success. It should be noted that during experimentation, not all effects could be found. This is to say that some effects of the device could be unintentional, although, it is highly unlikely considering the nature of the device, but this is still worthy of mentioning. These effects cannot be specified at this time due to them falling under the unknowns of the project. If these unknowns were to affect the measures of success, then a potential design modification would be required.

B. MEASURE OF SUCCESS

Measures of success for this project will be based on how well the shall statements are fulfilled. The primary measure of success will be an operational system that can provide sensor data, remotely, from three or more user chosen sensors, simultaneously. Another major measure of success will be if the device can operate in most environments and still function properly. This includes nominal weather conditions as well as rain and snow. It should also be able to operate properly through a range of temperatures that is at least equivalent to the operational range of the sensors selected. A further measure of success will be how cost effective the system is and how replicable and modifiable the system is. There should be extensive documentation of all components and the design should be buildable and modifiable by someone with limited electrical engineering experience. The system should not be expected to give data for a large region such as a city or county as resources are already available for this. As with any project in engineering there will always be ways to improve the design. Based on how well the system functions, the results of our measures of success, and customer satisfaction the design will be finalized.

C. ETHICS AND RESPONSIBILITY

For this design process we shall follow any and all engineering design standards and all standards and laws set by governing bodies to prevent risk and unintended harm to users of this device and their communities. For example, the device will not be rendered faulty or unsafe to the public if one error occurs during use of this product. This device has no foreseen negative impacts on the communities that decide to implement the product, but the potential positive outcomes are many. Communities will be able to see if the air quality in their homes, work places, and schools are safe for them and their children. Groups will be able to see what pollutants are specifically affecting the air around them and take the necessary steps to solving the issue.

IV. RESOURCES

Resource listings here are speculation for what tools, software, components, testing equipment, and software may potentially be required to complete the project.

- Visual Studios, Notepad++, or some other type of code editing software.
- Microcontroller integration software to program any boards that may be used.
- Arduino or Raspberry Pi boards. Currently unknown model.
- Port modules to be added to related microcontroller boards.
- Multimeters for voltage and amperage testing.
- Potentially a soldering kit, however, this will try to be avoided when making design choices.
- Hand selected air quality sensors. This is to be determined later when a standard for I/O ports has been made.
- Related cables and connectors to I/O ports.

Time is another resource that must be considered. The project is to be completed over the course of two semesters. With this in mind, time is not an unlimited resource. Estimating the hurdles and objects to pass, the allotted time should be sufficient to create a prototype of the device and allow for future development.

The last resource to consider is the budget. In order to stay in line with the goal of having a low-cost design, the prototype should be constructed out of materials with a monetary value under $100. Given that Raspberry Pi and Arduino boards can range from $10 to $80, further research into the most cost-effective option will need to be completed. Other resources are for designing the device itself as the software will be available for free online. The sensors themselves are not taken into consideration as the cost changes case by case. I/O port modules are inexpensive and only add at most $10 if not already present on the board.

A. PERSONNEL

This tells of the individual. What are the members of this team capable of doing and what will we need to learn? Talk about the skills that are expected by the team and if we currently qualify for them.

This part also talks about how we plan on obtaining the necessary knowledge to complete the project. I can go ahead and say that we have a lot of studying and research to perform before we are confident in success.

There are many different aspects of electrical, computer, and mechanical engineering that will be implemented within this project. As such, in order for our specifications to be met and shall statements verified, we will need to use an ample amount of time in research, design concept, and experimentation. Looking at various sensors and product standards will be some of the things we will need to look at. Finding the correct component/circuit/ or system will be a major factor to our development process.

All of the members on our team have studied over various circuits and how to implement them to do what the developer wants it to. I, Alejandro Moore, have had some experience in PCB circuit design, analysis, and manufacturing. Knowing what is the correct component to the system and analyzing how it should be used are things that I will need in order to understand and record the design process. I have also had some experience in BNC cable installation and other types of wires. Learning these concepts has given me resources I can share with the team if needed. Also, I am aware that my team members have other skills that can also be used within this project. This is beneficial for the functionality of our team, because it can help the others learn the concept and further the process of our project.

I, Marvo Odds, have had many experiences in digital logic projects,circuit design and coding projects. Many of these experiences came in the form of projects from my classes at Tennessee tech such as coil gun circuit, digital logic circuit that implemented the game Ship,Captain,Crew, and my coding projects in CSC 1300 that used C++. This is beneficial because our design will need knowledge in circuit design and coding to implement our website and databases.

I, Cameron Smith, know that this project will ask us to gain new skills and knowledge as we progress. This can be done by seeking guidance from experienced instructors, reading research in articles and texts, and observing other design projects. The skills I bring to the team are familiarity with C, C++, and assembly coding languages, programming microcontrollers, digital design, circuit analysis, and client/server communication design. I fully expect to learn more skills by necessity and not exclusive engineering related skills but also teamwork and group communication skills.

I, Joshua Egwuatu, have had experience in the field of engineering. I understand the design process in it's completion from start to finish. I also have experience in C++, Solidworks, and Altium. I also have a strong background in leadership and communication due to the many roles I've help in my academic career. I expect my skill set to be beneficial for the team, and I can't wait to pick up skills along the way!

I, Kaleb Irwin, have experience in coding primarily in C++, and a little bit in HTML as well. I also have worked with microcontrollers before and designed several small projects throughout my time in engineering at Tennessee Tech from making the game Shut the Box with logic gates to designing and building a coil gun. Almost certainly more skills and experiences will be required during this project and I am looking forward to getting started.

B. TIMELINE

1) Project Proposal: September 25th, 2022
2) Conceptual Design & Planning Final: October 30th, 2022
3) Detail Design Draft 1: November 10th, 2022
4) Detail Design Draft 2: November 24th, 2022
5) Design 1 Final: December 11th, 2022
    a) Final Presentation for Design 1
6) Design 2 Draft: March 6th, 2023 (Estimate)
    a) Prototype
    b) Website Completion
7) Final Presentation: April TBD, 2023

All things related to time: how long it can potentially take, what parts will take the longest, deadlines for important tasks, and how much time we have. We can mention more about the scope of the project and flexibility of the times. We cannot guarantee any times that are given in this section. We are taking guesses. There are plainly too many unknowns to have a definite timeline.

We need to include whatever a Gantt chart is here. It must look professional and show the team members, their tasks, and expected completion dates of said tasks. This chart should also have important dates like Fall Break, Thanksgiving, Christmas etc.

REFERENCES

References follow a specific format depending on what it is.

A book would have this format:

[#] Author,*Title*, volume, edition. City, State, Country: Publisher, year.

A website would have this format:

[#] Author. "Page." Website. URL (accessed month day, year).

[#] "Air Quality Sensors." *Air Quality Sensors | Air Quality Tracker Airly*, https://airly.org/en/features/air-quality-sensors/

[#] "Cookeville Air Quality Index (AQI) and Tennessee Air Pollution." *IQAir*, https://www.iqair.com/us/usa/tennessee/cookeville.

For anything else, go here:https://owl.purdue.edu/owl/research_and_citation/ieee_style/reference_list.html

References are always numbered in order of citation they appear in the text. We do not have to do citations at the bottom of every page when we use one as far as I can tell. We do however need to number them and recall the order for the REFERENCES section.