Large Scale Early Warning System
for
Deadly Environmental Elements

ENGG2990G

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Abstract

Our project, *Aerity* (Air and Purity), was initiated to protect people and prevent unnecessary deaths due to the increasingly imminent danger of various invisible elements that exist in our daily life. We have developed a network of sensors that are located around the country that detect the levels of lethal elements: smoke, harmful gases and radiation. These sensors provide real-time data which is uploaded to the Internet through the use of Raspberry Pi. The public can then access this information through an interactive map on a user-friendly website. On top of that, *Aerity* keeps users aware and alert about their immediate surrounding as it will generate a warning alarm whenever there is a dangerous level of smoke, gases and/or radiation that is beyond the safety threshold. Due to its affordability, communities within and outside Hong Kong will be able to access such vital information and take immediate action to keep themselves and their families from harm.

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1. Background

There are many invisible airborne elements that threaten our day-to-day health: smoke, pollution, radiation and gases. These elements can be found in the very air we breathe, and they are often byproduct of industries or factories. Not many people are aware of the danger that these elements pose, and this can prove to be very fatal.

The 2015 Southeast Asian Haze was an air pollution crisis that caused a significant deterioration in air quality across several countries in Southeast Asia (Euan McKirdy, 2016). Millions of people had no choice but to inhale the dangerous particulates from the smoke which caused hundreds of thousands of cases of acute respiratory disease. Nineteen people had died from chronic heart and lung illnesses. 4 out of 5 team members come from Indonesia, and have had friends and families who were directly or indirectly affected by the smoke.

In addition to smoke, radiation also plays a major role in causing an increase in death tolls. For example, up to 2014, the official number of fatalities caused by the Fukushima nuclear disaster in 2011 had reached 1,232 (Guiterrez, 2015). Fukushima habitants are now facing various health problems associated with the nuclear meltdown.

1.1 Invisible Dangers in Our Daily Life

Both smoke and radiation are dangerous to humans' health; they are somewhat omnipresent in our daily lives. Yet, not as many people are aware of the presence of such elements in their environment and how they present a major health risk. Knowledge about these elements are vital to understand the dangers we face:

1.1.1 Smoke and Gases

Smoke is a collection of airborne solid particulates and gases emitted when a material undergoes combustion. Inhalation of toxic smoke caused by incomplete combustion of fuel gases or any organic compound could be acutely dangerous to health. Smoke which mainly consists of soot (carbon) and tiny particles is problematic not only for health but also for the environment. Every year, there are 700 to 900 deaths due to smoke inhalation.

1.1.2 Radiation

Radiation is the transmission of energy in the forms of waves and particles through space. It may cause cancer; there is an accepted limit of radiation exposure that a body could tolerate. Our bodies could not register the radiation until it passes a certain threshold. As a result, symptoms of acute radiation syndrome (ARS) may go unnoticed without appropriate medical diagnosis. In Hong Kong, a possible cause of radiation is from Daya Bay Nuclear Power Station located in Shenzhen, 50 km away from the center of Hong Kong area. It poses a huge risk to the Hong Kong residents if there was a leak from the station. Aerity would inform the local residents immediately if there was a leak, thus allowing them more time to take action without having to wait for announcement from the government or through the media.

China has a history where the air pollution had been reported in a misleading way, blocking the public understanding and enabling official inaction (Andrews, 2014). Therefore it is important that the residents have access about this data from a neutral third party.

1.2 Objectives of Our Project

The purpose of this project is to create a network of detectors that display pollution levels in different regions; users can check the data in various locations of their choosing, whether it is at residential neighborhood, office districts or for travel.

Our specific objectives include:

- To design a network of smoke and radiation sensors that are spread out over a large area and able to display real-time data, integrated with google map, on a website accessible to all.
- To inform the users about the level of danger and allow them to take action.
- To minimize and prevent casualties if events such as the nuclear meltdown or massive haze shall occur.

1.3 Our Logo

Figure 1 Aerity logo

Aerity is derived from the words “Air” and “Purity”. It is inspired by the tragic incidents of forest fire in Indonesia ("What causes South East Asia's haze?", 2015), the home of our team members. The fire incidents have resulted in a smoky haze with strong smell of burning wood and foliage veiling the Southeast Asian region for more than three months. It

caused 19 deaths and imperilled the lives of human beings due to the occurrence of chronic obstructive pulmonary diseases as an impact of haze. A study found that the impact of haze wave has a deteriorating effect on the health of millions of people with an average of 110,000 deaths every year in the region due to seasonal exposure to smoke particles (Johnston et al., 2012).

Thus, Aerity was developed in order to better equip every individual with an early warning system that lets humans stay aware and alert about the current air quality level.

The idea of this project is reflected in the logo (see figure 1) where a chain of connected circles safeguards the earth in the middle. The circles resembles the network of sensors that can detect radiation as well as harmful gas and smoke particles.

2. Design and Methodology

The idea of having a network of sensors or detectors that will send data to a website was actualized by the use of a Raspberry Pi and pollution sensors. The MQ-2 Smoke sensor, and Geiger radiation sensors are used to collect levels of smoke and radiation respectively. These data come out as the output of the sensors, and sent to the Raspberry Pi. Raspberry Pi is a low-cost, credit-card sized, single-board computer. One Raspberry Pi and the sensors make one unit of "pollution station"; these stations will be then located in various regions in the area.

The data is processed in a program in Raspberry Pi in Python language to transform them to a JSON file. This file will be then transmitted to the *ihome* server. On the website, the JSON file will be read and processed into displayable data. These data also provide the safety status of the particular region concerning each pollutants. The users can check the hazard level of certain locations, which will be shown on the map.

2.1 Overview

Our data flow consists of three main parts: recording sensor inputs, reading and processing sensor inputs, and analysing and displaying the data on website. In the first part, the smoke/gas, and radiation levels are detected by a MQ-2 sensor and a Geiger-Muller tube sensor, respectively. The data collected is then stored using a Raspberry Pi 2 Model B. Furthermore, we extract the data from current.JSON by using a Python program and the data will determine whether the area is safe. The current data recorded is stored in record.JSON file, which consists of previous current data. In the last part, the data is extracted from current.JSON and displayed on the website through graphs and charts.

3. Hardware

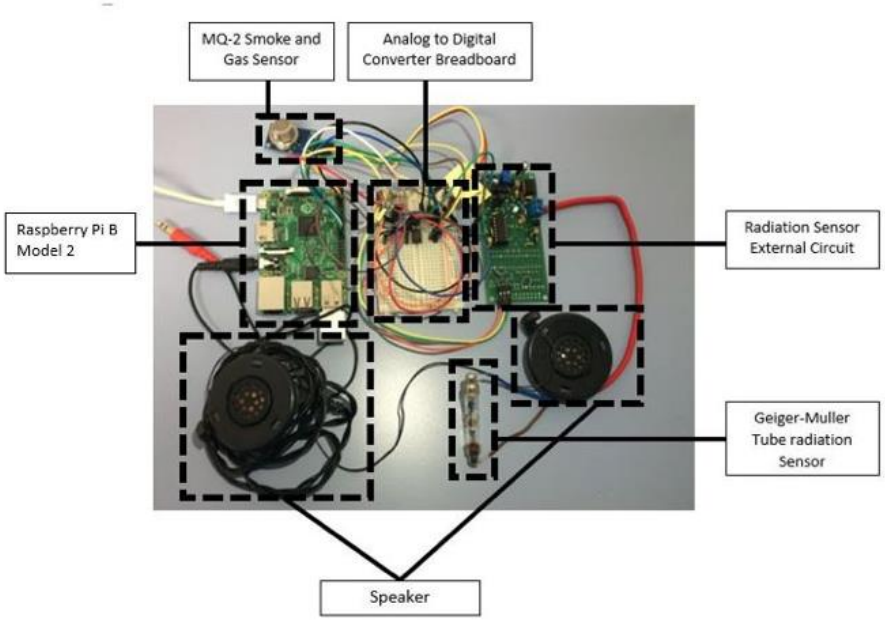

Figure 2 The hardware of our project

This is the system we built, and it consists of:

- MQ-2 Smoke & Gas Sensor,
- Analog to Digital Converter Breadboard,
- Raspberry Pi 2 Model B,
- Radiation Sensor External Circuit, and
- Geiger-Muller Tube Radiation Sensor.

4. Software Development

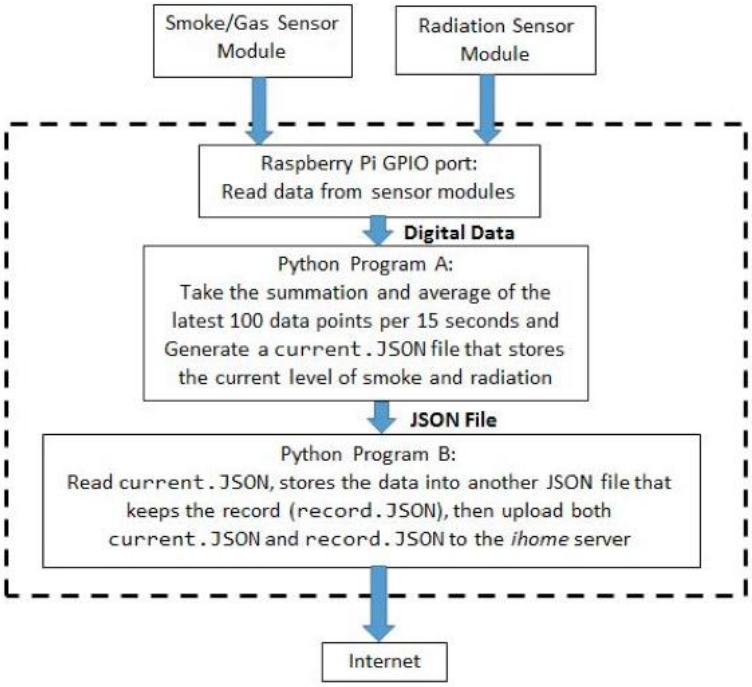

Figure 3 System data flow

4.1 Python Program A

There are two programs written in Python in the Raspberry Pi; they are the ones necessary to extract data from the sensor. Python program A is the python program which takes value from the GPIO pins i.e. value from the sensors. Python program A works for both the MQ-2 and the Geiger sensor. It takes the summation of the most 100 recent readings per 15 seconds, and find the average level. Every time a new level is read, the oldest data is deleted. Therefore, in any point in time, there are only one hundred readings in the program. Based on this average; the program would decide if the area is dangerous or not.

These data would then be compiled into JSON files which would then be processed with the Python program B.

4.2 Python Program B

Python program B reads the JSON file generated from Python program A; it stores the entries into two different JSON files. The first JSON file stores the current situation, whether the area is safe in that particular moment in time. The second JSON file stores a record of the previous sets of information. It is useful to see the trends of the pollution levels, and this set of data can be displayed in graphs and charts later on. Both JSON files are then uploaded to the *ihome* server to be displayed in the website.

5. Contributions

5.1 Mika's Contributions

- Budgeting
- Material Purchase
- Hardware Development
    - Setting up Wi-Fi adapter to raspberry pi and making sure it works/connects to the network.
    - Assemble the raspberry pi with radiation and pollution sensor by soldering the component together with the corresponding electrical components such as IC, resistors, and switch (if necessary).
- 3D Printing
    - Designing the lid and the bottom of the product's case by using Rhino's Lab as the designing platform
- Data Collection
    - Collect data obtained from the raspberry pi and manage the data output to ensure there is no error calculation.
    - Analyze data obtained from sensors, such as CO2 levels or radiation levels to meet the standard safety level and set the risky level on the website.
- Miscellaneous
    - Prepare and carry out presentation to inform audience on what we have done
    - Project management such as setting timeline for the project, carry out presentation and gather materials presentation

5.2 Jenny's Contributions

- Software Development
    - Installing operating system
    - Designing the webpage from scratching using HTML/CSS, PHP, & JavaScript
    - Working with data received from Raspberry Pi to output onto the website
- Programming
    - Python programs to receive data from Raspberry Pi
    - Analyze data to display on the front-end of website
- Logo Design
    - Brainstorm ideas
    - Fix colors and sizing of image
- Poster
    - Create poster for presentation
    - Ensure all text is readable
    - Fix colors and sizing of figures

6. Reflections

6.1 Mika's Reflection

To begin with, joining President's Cup was a crucial stepping stone during my study in HKUST since I was able to get out of my comfort zone. Having said that, a year-long commitment for this competition made me realize that what it felt taking risks and utilizing my capability into maximization. Given the background of my study, I felt small on how I could contribute to the team when Felicia recruited me for this project. However, due to all supports from the teammates and encouragement from advisor, I was able to adapt to the learning environment as I encountered coding and hardware problems in the making of our sensors. I might not be the expert in those two field but the learning process that I gained was invaluable experience since it motivated me to explore field outside my major concerns.

Since our group consists of students who come from multidisciplinary background, throughout the process, I learnt on how to work with students from different major and how to think in their perspective. Arguments could not be avoided as there were disagreements, such as choosing the design of the case which took us about 2 weeks just to find the right design which could please everyone. Nevertheless, the process of design thinking and other problem-solving matter helped to nurture me as an individual since it taught me how to be more creative in approaching different problems and how to communicate my idea effectively within the group. The important takeaway from this project is that I learnt how to be not a passive-aggressive individual. Working under pressure made the atmosphere a bit tense occasionally, and being either passive and aggressive about something would not give any help but more tension. By understanding on how each member work and think is the crucial element when working in a team to maintain the conducive environment.

Moreover, I learnt how to manage my responsibility really well between the project and school work. Devotion on the project made me to get through all the hardship that I have encountered, especially when I was assigned to be responsible on assembling the sensor. I have never done any hardware assembling before and took part in that field was terrifying at first since I felt that I might not do well. I have encountered a lot of mistake but determination for success was the motivation key I had in mind to complete the task with my best ability.

Our hard work finally paid off when we had our demo in front of the six judges. Based on my observation, we did impressive job during the demo since we were the only all second year girl member group. Praise were given by some of the judges and it felt amazing to complete this kind of task. Learning experience has not been this fruitful and enjoyable. I would personally thank my advisor, Prof. David Rossiter for his guidance and patience in supervising us throughout this project. Without his presence, we would not get through the semi-final selection and demo presentation through his constructive critics and patience.

Last but not least, this competition has shaped me into more mature and critical individual that widen my knowledge and enhance my interpersonal skill.

6.2 Jenny's Reflection

Being an exchange student, I never would have imagined myself spending a majority of my time on a student-initiated project.

I'm so glad I am a participant of President's Cup, because I was able to gain a new set of skills and be a part of an amazing team. I already had an interest in web development, so building the website for our product seemed like it would be a breeze for me. However, I did not think about the new programming languages I would have to learn to use to connect the back-end with the front-end. The most important concept I learned (to me) was how to use APIs. I always wondered what an API was and how to use it, but I never really got around to actually using it myself. However, for our website, we wanted to build a map and we used Google Maps API to be integrated onto our website to display the information we wanted. It was at that moment that I realized what an API was and how to use it. This would not have been easily achieved without my amazing team. I did not know how well I would work with my other teammates, because I had just met them, while everyone else knew each other already. But I'm happy to say that I worked well with everyone, especially with Felicia because we had to constantly communicate in code.

Overall, I would love to participate in a student-initiated project/class again, because everything I learned is by students and for the students. I had a lot of control and flexibility in the project, because I was able to decide on the programming languages to use for the software development, what hardware to use, and many others. I was able to learn at a comfortable pace with an advisor to guide me on the correct path, when I went off the tracks.

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