COMP4971C

Low-Cost Air Pollution and Radiation Monitoring Network for Disaster Prevention

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Abstract

This project 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. A proposed network of sensors will be located around the country to 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, it keeps users aware and alert about their immediate surrounding as a warning alarm will be generated if the level of dangerous smoke, gases and/or radiation reach beyond the safety threshold. Given its cost-effectiveness of this project, communities within and outside Hong Kong will be able to afford to deploy this system in order to retrieve such vital information and take immediate action to keep themselves and their families from harm.

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1. Introduction

Many invisible airborne elements such as lethal smoke, gases, and radiation have always been a threat to human health. These elements can be found in the air we breathe, and they are often by-product of industries or factories. Not many people are aware of the danger that these elements pose, and this can prove to be very fatal. For example, 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 died from chronic heart and lung illnesses. In addition, radiation also plays a major role in causing deaths. 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 deadly health problems associated with the nuclear meltdown.

It is evident that even in Hong Kong per se, thousands of people die due to huge amounts of air pollution in Hong Kong each year (Lai, 2015). Hedley Environmental Index has shown that even from midnight to 12 noon on 2 May 2016, 229 patients have to be confined to bed because of health impairment due to severe level of air pollution in Hong Kong. Not only has Hong Kong, the rest of the world also suffered from the danger of air pollution.

Based on these problems, a network of smoke and radiation detectors were built in order to give early warning to the public when the level of smoke or radiation in a certain area gets dangerous. Each set of detectors includes both smoke and radiation sensors, and having multiple sets of these detectors spread around the country would enable us to obtain relevant information about the level of smoke and radiation in the area. To show

the data to the public, each set of detectors sends the data collected to a server in the Internet on a real-time basis. When the level of either smoke or radiation gets dangerous, the detector would give an alarm sound to warn the people nearby. The data is sent to the server, and a program in a webpage reads the data and shows the data on the page. The data is shown in the form of a map, and several markers are displayed on the map, indicating the location of the detector and the level of smoke and radiation at the corresponding area.

2. Project Development

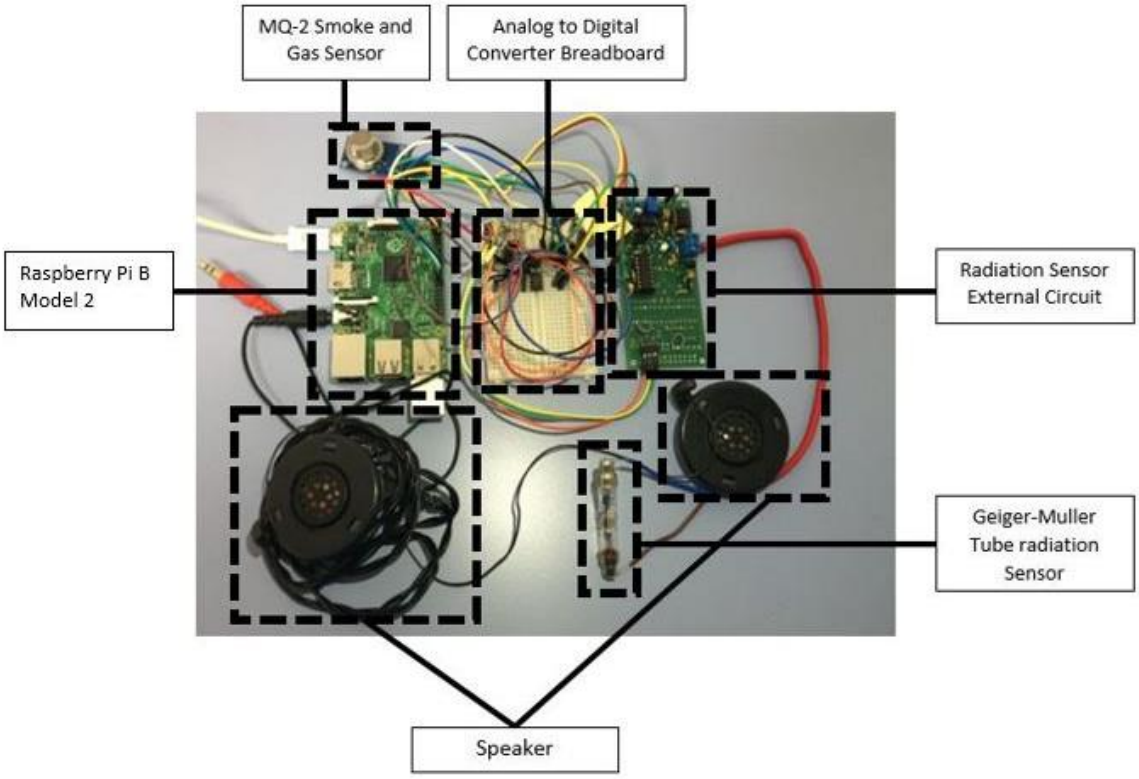

Figure 1: One Set of Smoke, Gas, and Radiation Detector

The hardware components of this project consist of:

1. Raspberry Pi computer: It is a single board computer where the data from the sensors are transferred through the Raspberry Pi. A python program in the Raspberry Pi would read the data and send it to the server.

2. MQ-2 Smoke Sensor: Reads the level of smoke in the vicinity and outputs the data in the form of analog data.
3. WiFi dongle for Raspberry Pi: Enables the Pi to connect to the Internet.
4. Geiger-Muller Tube: Reads the level of radiation in the vicinity.
5. Radiation Sensor Board: Interacts with the Geiger-Muller tube and converts the reading from tube into a voltage (analog data).
6. MCP 3002 Analog to Digital Converter: An integrated circuit (IC) that converts analog data to digital data. Since both the smoke and radiation sensors give analog data, this IC is needed since Raspberry Pi only reads digital data.
7. Breadboard: All electronic components, including the MCP 3002 analog to digital converter are connected on the breadboard.
8. DuPont Wires: Used to make the connections between components on the breadboard.
9. Speaker: Makes an alarm sound when the level of either smoke or radiation gets dangerous.

The data flow consists of three main parts:

1. Recording sensor inputs

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.

2. Reading and processing sensor inputs

   The data received by the Raspberry Pi is saved into `current.JSON` by using a Python program and the program will determine whether the area is safe. The current data recorded is stored in `record.JSON` file, which consists of the record of previous data. Both `current.JSON` and `record.JSON` are uploaded to the website server.

3. Analysing and displaying the data on website

   The program in the server extracts data from `current.JSON` that was previously uploaded and displayed on a map in the website. The data from `record.JSON` is used to show the graphs and charts showing the trend of smoke, gas, and radiation level. Users can then access the data and take action accordingly.

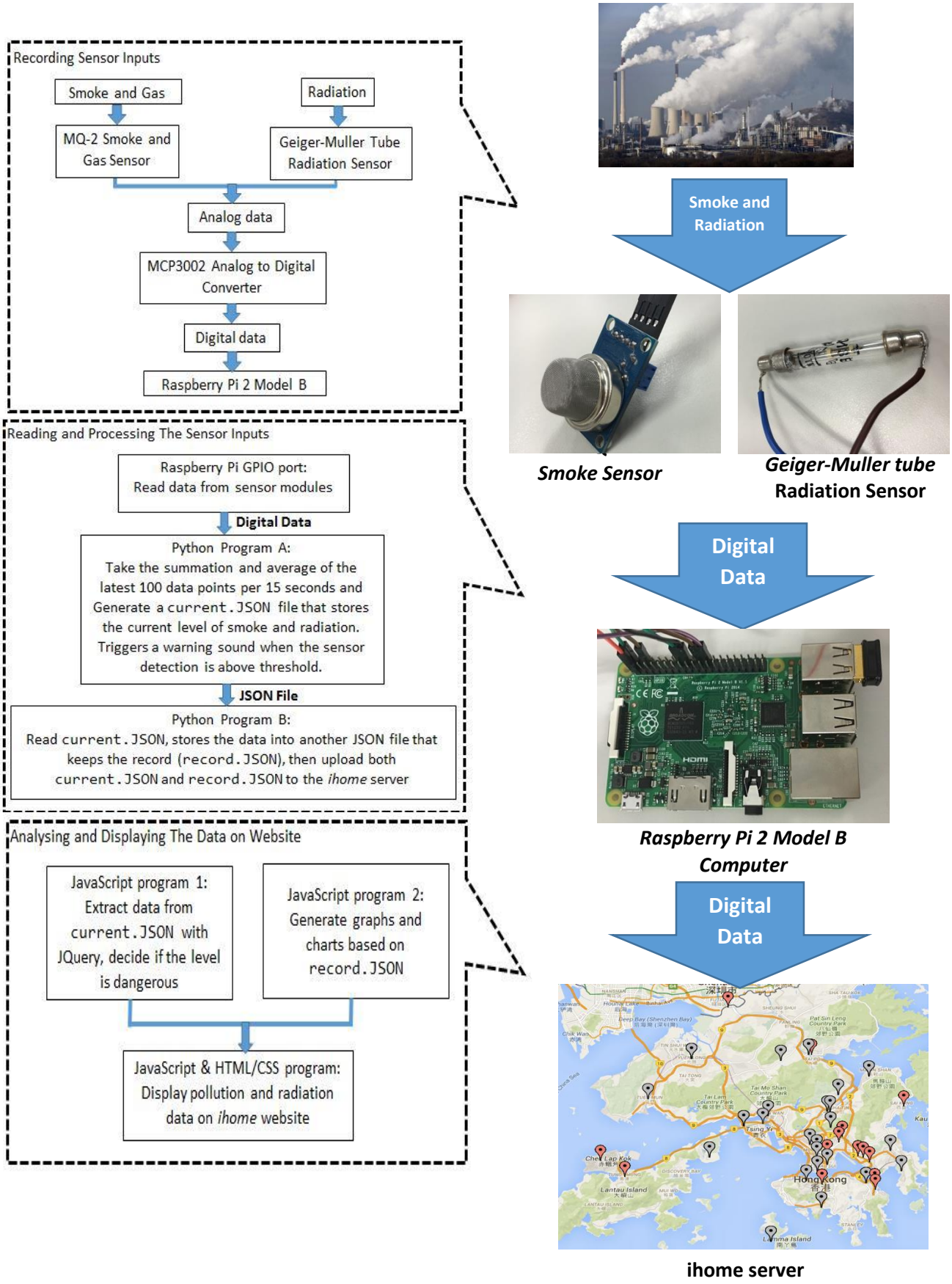

Figure 2: Data Flow

3. Cost Analysis

Cost Breakdown of Final Product

Item	Unit Cost (in HKD)	Qty	Total Cost (in HKD)
MQ2 Smoke and Gas Sensor	17.6	1	17.6
Geiger-Muller Tube Radiation Sensor	43.8	1	43.8
Radiation Sensor Circuit	139.7	1	139.7
Raspberry Pi Zero	40	1	40
DuPont Wires	7	7	49
3x3 inches PCB	4	1	4
MCP3008 Analog to Digital Converter	12	2	24
MicroSD Card 16 GB	38	1	38
Wifi USB Adapter	80	1	80
5V 2.5A Raspberry Pi 2 Power Supply	20	1	20
Speaker	10	1	10
Grand Total			**466.1**
Equivalent to USD*			**60.06**

*USD1=HKD7.76

For the development of the product, Raspberry Pi 2 Model B was used. However, the final product would use Raspberry Pi Zero which costs much cheaper and could perform the same task. In addition, breadboard would be changed to printed circuit board (PCB) as the design would be finalised. Also, PCB can be mass-produced and be purchased at a lower price. According to the cost analysis, this project will cost HK$ 466 or approximately US$ 60.

This project is proven to be more cost-effective as compared to other existing products in the market. Most of the existing products cost more than US$ 200. Hence, it democratizes our air quality monitoring platform to be widely used for the larger user base be it from the underprivileged neighbourhood or the well-off community.

4. Product Case

This project is also equipped with a product case which is especially designed for a better user experience. The design was made using Rhinoceros 3D software. After several attempts of designing the case, the final design was printed using a 3D printer called UpBox.

The product case allows users to use this system without much hassle. It reduces the set up time as well as maintenance work. The gentle curves creates an aesthetic accent of this project while at the same time functions as a durable protection for all of the hardwares inside.

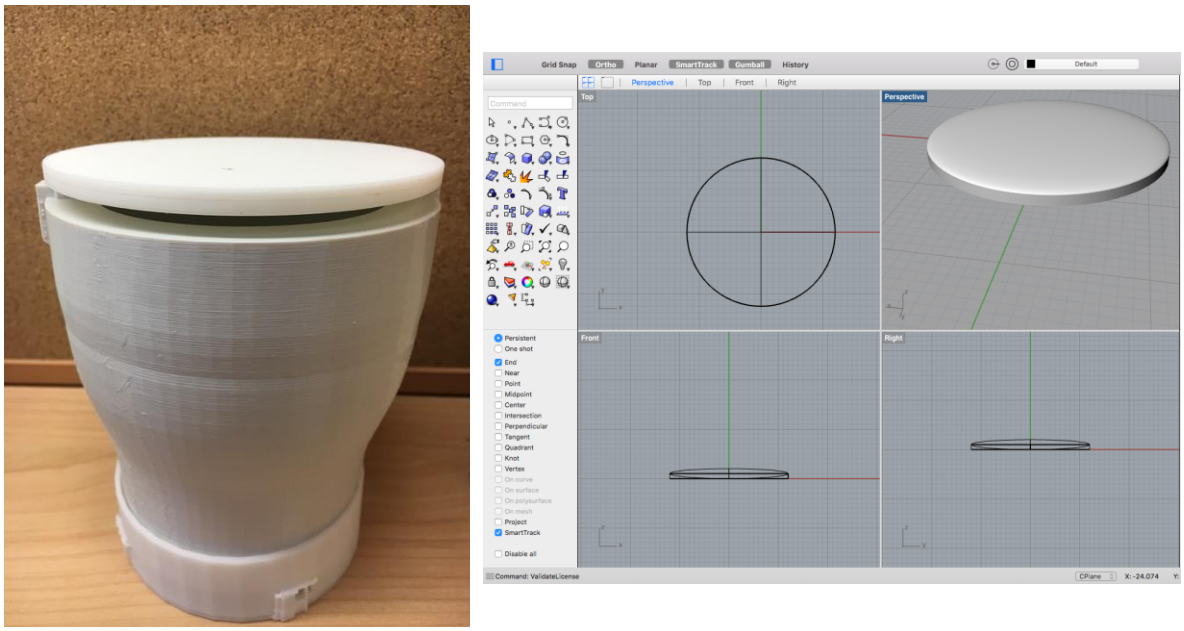

Figure 3 Product Case

5. Future Project Development

There are still many improvements that can be made in order to increase the impact of *Aerity* to different communities across the globe. Currently, the users need to access the data through the website. In order to provide a more personalized data relevant to a particular user, one possibility is to develop a mobile application that will run both Android and iOS. This mobile application would thus be able to warn anybody who owns and carries a smart device in their pocket, and keep them from harm wherever they go.

Another possibility is to expand the features in order to detect a greater types of deadly elements in the environment. The initial plan had included the sensors not only for Smoke and Radiation, but also for Carbon Monoxide gas. Carbon Monoxide, also called "Invisible Killer", replaces the Oxygen in the blood and kills off cells. Its odorless, tasteless, and colorless nature causes people to die without ever knowing what hit them. Surviving victims would suffer from a range of permanent problems such as brain damage, heart problems, and major organ dysfunction. It was realized that it would not be possible to integrate the sensor within the time constraint of the project, however, it is vital to increase the capacity to be able to detect more deadly elements in the environment.

In order to encourage the use of the project in low-income communities, the cost of production can be reduced by using Raspberry Pi Zero. Raspberry Pi Zero is at least five times cheaper than the previous models. Various governments and NGOs can adapt this project easily in low-resource settings. This allows not only the middle-upper class, but also the low-income families to keep themselves from harm.

6. Conclusion

This project was intended to save people's lives from the imminent danger of invisible elements in the air which, often times, pose a threat to the environment and human health. The result of this project is a network of sensors that are spread across different locations which detect the level of lethal elements: smoke, harmful gases and radiation. These sensors collect real-time data and upload them to the internet through the use of Raspberry Pi computers. The public can make use of this information through an interactive map on the project's website. Besides, the system will generate a buzzing alarm if the local area has smoke, gas, and/or radiation levels beyond the safety standard. It enables users to be vigilant of any potential environmental hazard and take quick action to save their lives. Due to its affordability, basically everyone, from the low-income neighbourhoods to the more well-off areas, will be able to access such vital information and keep themselves and their families safe from harm.

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