ALCU Region III Research Journal
ISSN 2672-2143

A Pollution Monitoring System Using Arduino Microcontroller for Norzagaray Municipal Environment and Natural Resources Office (MENRO)

Mindalita Ocampo-Cruz and Caple Jun Lipa
Norzagaray College

Clean air is an important necessity that human beings need to survive. However, with the existence of various plants and other pollutant- emitting materials, the clean air has been sacrificed and health issues arise. The device for monitoring air pollution developed by the researchers can be a useful solution to help the MENRO of Norzagaray, Bulacan in establishing a clean air environment. The device was tested with various air pollutants - butane gas, liquid particles, cigarette smoke and gas particles at various distances. Researchers recorded the time of response (measured in seconds) and found out that butane gas has the fastest notification while liquid particles has the slowest response to the users' mobile phone. In terms of system evaluation, all aspects of the system were outstanding. Researchers recommend the implementation and use of the device and financial allocation from the local government of the selected beneficiary.

Keywords: Air Pollution Monitoring System, MENRO, Arduino Microcontroller, Norzagaray, Bulacan, Norzagaray College

Introduction

Air pollution is a continuous and growing problem these days. With the increase of the use of vehicles on the road which can be encountered mostly at metropolitan areas, the atmospheric condition is highly affected. The air quality is no longer safe for everyone. Air pollution could be a cause of mild to serious health problems that include allergic reactions, such as irritation of the throat, eyes and nose and as well as heart and lung diseases. Monitoring must be implemented to avoid and prevent those complications.

The monitoring of air pollution could be also done with the use of the Internet of Things or the IoT technologies. IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people who are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Wikipedia). With the use of Arduino platform, a system and a device could be combined to create an air pollution monitoring system that will trigger an alarm when the air quality goes down or beyond a certain level because it means that there is sufficient number of harmful gases that are present in the air to provide a real-time result which will benefit the users.

Several similar systems were developed in different countries. VasimUstad and A. S. Mali et.al (2014) introduced and simulated an air pollution monitoring system based on the wireless sensor network, to monitor concentration level of air pollutant in the environment due to the industrial process. The proposed system collects information about pollutant CO, SO2, and dust concentration; the hardware architecture of system consists of the sensor array (CO, SO2 and dust) PIC16F887.

Ustad, Mali and Kibile (2014) implemented ZigBee based wireless air pollution monitoring system with low cost and energy efficient sensors. The system consists of integrated mobile DAQ with PIC 16F877microcontroller, sensor array (MQ family- 131,135,136), GPS module, high-end PC as pollution server, and Zigbee modem. Sensor array aggregates information about concentration level of CO, SO2, and NO2 through op-amp based signal conditioning for the microcontroller. The software architecture design of system is engaged in different functions such acquiring real-time information, physical location, time-date of pollutants, encapsulation of data, transmission of data to pollution database server which interfaced with Google Map to provide 24/7 information presentation. The user interface for this system is presented using advanced Visual Basic application and also on 16x2 LCD display.

James J. Q et.al (2012) developed air pollution monitoring using public transportation system for Hong Kong to perform simulation of system sensor nodes which were deployed on the city buses and implemented using Chemical Reaction Optimization (CRO) to achieve better optimization by using formulated BSDP (bus sensor deployment problem) in the evaluated coverage percentage, total number of sensors, data accuracy and performance. Comparison of obtained values of 'c' with CRO, SGA and SRM was made to decide which meta-heuristics was better to solve BSDP.

Elias Yaacoubet.al (2013) described real-time ambient air quality monitoring system. This was developed using distributed air pollution monitoring MGMS stations which are able to communicate wirelessly with backend QMIC developed pollution server. Every MGMS static sensor node was built using gas sensors array to sense CO, O3, NO2, H2S, SO2, NO and meteorological sensors for sensing temperature, relative humidity powered with solar panel in addition to data acquisition as well as wireless communication. A total of four static sensor nodes (Qatar1-Qatar4) were deployed to cover an area of 1 km2. Air pollution server aggregated information about real-time ambient air pollution using 4 MGMS static node and uploaded and delivered it to end-users through website and mobile application.

Chaundry (2013) came up with a proposed environmental monitoring system called ArduAir which is a small and portable measurement system which includes various gas sensors (such as CO, CO2, NO2, O3, etc.) and microcontroller that can be used by a number of persons simultaneously. He proposed a software for collecting data from the ArduAir and plotting them in real-time which will provide the user with (i) low-cost and low-power measurement hardware that is suitable for mobile measurement, (ii) user-friendly data collection and processing software, (iii) high quality data and (iv) easy-to-use instrument that can be used commercially by a large number of people. The author, for sample purposes, connected one CO sensor to a module called an Arduino microcontroller which is then connected to a computer through a serial communication. The data collected by the Arduino microcontroller from the sensor are then sent to the computer software where they get recorded and plotted in real-time. In this way the ArduAir is designed and built in a small size to be portable and as low-cost air pollution monitoring system to monitor CO. The author suggested that this sensor-based system can also be used for various other gases such as SO2, NO2, CO2, O3, etc. using different sensors. This system can thus be utilized effectively by the general public for monitoring the quality of air around them.

The Municipality of Norzagaray envisions a safe and ecologically sound environment that will pave the way towards the protection of public health not only for the benefit of its present inhabitants, but more so for the future generation through a sustainable and integrated solid waste management program

ISSN 2672-2143

within the context of sustainable development moving towards the threshold of a zero-waste municipality by 2015.

Norzagaray MENRO aims to successfully attain an environment-friendly, clean and green community. To attain this, sustained efforts in the adoption of the provisions of RA 9003 must be achieved to the fullest extent and all sectors of society must be mobilized to ensure the success and sustainability of the integrated solid waste management program that will henceforth result to the implementation of proper segregation, collection, transport, storage, and treatment of solid waste and shall work for the attainment of the best environmental practices in ecological waste management.

At present there are three large cement factories in the town that continuously hamper the air condition of the place, making it more hazardous to nearby barangays and their people. This is the reason why the proponents of this study came up with the concept of creating a device that will monitor the condition of the air and send notifications to the beneficiaries. The study aims to help MENRO in monitoring the condition of the air to possibly reinforce and create actions to further maintain the clean atmosphere of the town.

Statement of the Problem

This study aims to create a device that will monitor the air condition and level of pollution in Norzagaray, Bulacan.

Specifically, it sought to answer the following problems:

1. How will the device monitor air pollution that occurs when harmful substances including particulates and biological molecules are introduced into Earth's atmosphere?

2. How will the device notify if the air quality is no longer safe?

3. What is the evaluation of the users on the device in terms of:
   a. Correctness
   b. Reliability
   c. Efficiency
   d. Integrity
   e. Usability
   f. Maintainability
   g. Testability
   h. Flexibility
   i. Portability
   j. Interoperability

Methodology

Research Design

This study used experimental and descriptive approach. Experimental method was used in creating the device and testing its capability and reliability. Descriptive method was used in analyzing the results and the performance recorded during the tests to create and arrive a more comprehensive and reliable study.

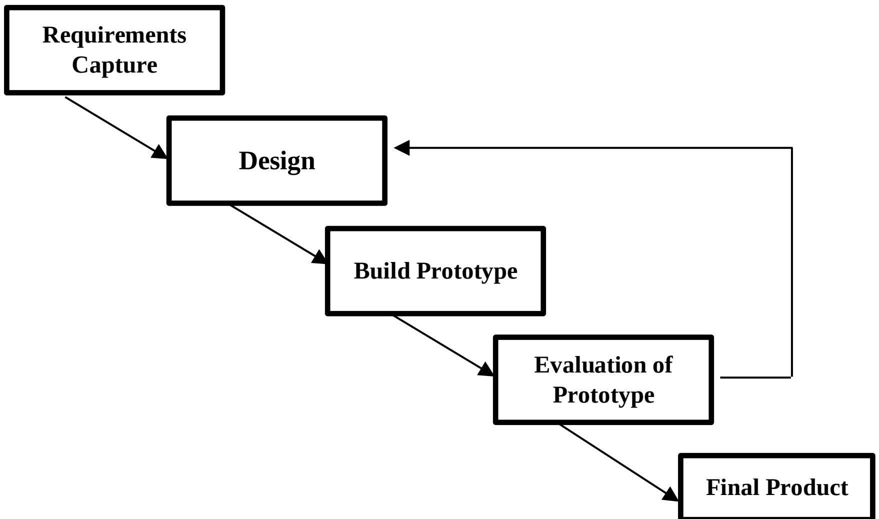

Figure 1. Prototype Model Process

The prototype model process is shown in Figure 1. The process starts with the requirements in building the prototype which refer to the software and hardware requirements. The proponents collected and presented the details of the current system including the information needed by the users to perform their job. To obtain more knowledge, the proponents relied on the previous study on documentary sources which includes published and unpublished documents. The logical design of the proposed study was presented through the use of analytical tool.

Using Arduino Microcontroller, the proponents used the gathered materials to focus the system design to work on the prototype use for evaluation of a new design or to enhance precision by system analyst and user. It also served to provide specification for a real working system than a theoretical one.

Software evaluation aided the proponents to measure the system's extension, correctness, reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability, and interoperability. It illustrates the strength of the system in some aspects and its weakness from which revision must be undertaken and the need to return to the previous level.

Testing the Prototype

The prototype underwent four (4) tests using different particulates and air pollutants – butane gas, dust particles, liquid particles and cigarette smoke. Each pollutant was exposed at a varied distance (in inches) from the device and the response notifications to mobile device were recorded by seconds (see Table 1.)

ISSN 2672-2143

Table 1. Testing of Pollutants Samples

Pollutants	Distance (Inches)	Responses (Seconds)			
		1st test	2nd test	3rd test	Average
Butane Gas	2 inches	110.04	110.01	109.64	109.90
Dust particles	5 inches	111.23	112.32	116.49	113.35
Liquid particles	5 inches	140.01	131.23	132.15	134.46
Cigarette	6 inches	122.67	121.05	121.26	121.66

Each pollutant was also tested thrice to the system to determine the consistency of the results. When looking at the results, it is observable that there is a varied result when it comes to the time of response or the delivery of the notification. It is also noticeable that among the pollutants tested, butane gas has the fastest response while liquid particles have the slowest arrival of notification.

Research Instrument

The proponent used the system evaluation rubrics adapted from ISO which evaluates the system according to its correctness, reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability, and interoperability. A 4-point Likert's scale was used to measure the response of the users.

Table 2. Likert's Scale

Scale	Range	Descriptive Scale
4	4.01 – 5.00	Outstanding
3	3.01 - 4.00	Very Satisfactory
2	2.01 – 3.00	Satisfactory
1	1.00 – 2.00	Poor

Statistical Treatment

The data of the study were treated with SPSS 22 for more accurate results. Weighted mean was used to determine the commonality of the responses and results of the tests.

Results and Discussions

After the series of tests using different pollutants, the performance of the device was evaluated by the users and the results of the responses are shown in the succeeding tables.

Table 3. Performance Evaluation of the Device (Weighted Mean)

Criteria	Overall Mean	Verbal Interpretation
Correctness *Completeness of the system is concern. System can generate accurate result.*	4.57	Outstanding
Reliability *System can handle failure set by the user or has an error handling feature.*	4.27	Outstanding
Efficiency *System can run longer hours; outputs are correct in generating reports.*	4.45	Outstanding
Integrity *Security is reinforced. System is protected by a username/password and can trap unauthorized user.*	4.39	Outstanding
Usability *Needs of the end-user is obtained operationally approved for implementation.*	4.50	Outstanding
Maintainability *System can describe/locate the errors during runtime. Ease of identifying what needs to change as well as ease of modification and re-testing.*	4.41	Outstanding
Testability *Ease of validation, that the software meets the requirements.*	4.55	Outstanding
Flexibility *Ease of changing the software to meet revised requirements.*	4.50	Outstanding
Portability *The extent to which the software will work under different computer configuration (i.e., operating systems, database etc.).*	4.45	Outstanding
Interoperability *The extent or ease to which software components work together.*	4.58	Outstanding
Overall Weighted Mean	**4.467**	**Outstanding**

The results revealed an overall mean of 4.467 interpreted as Outstanding. This means that the system is recommendable to be used for the said purpose. However, further development shall be initiated to fully utilize the potential of the system.

Meanwhile, when looking at the means of each of the elements on system evaluation, all elements were rated outstanding. Interoperability of the system has the highest mean which means that the software components of the system used work together. The system also generates correct notifications and reports (correctness and efficiency) and handles failure or error in handling by users (reliability). In terms of testability, the system passed the validation and evaluation of the users as the software meets the requirements.

To further test the system, the system was also tested in other mobile phones to determine if it generates notifications. The test was successful; thus, the flexibility requirement of the system was met. The system works on different system configurations as well as different operating system and databases (portability).

ISSN 2672-2143

To establish privacy and integrity of the system, the proponents set up a privacy protection using a password to trap unauthorized users. Because of its simplicity, the system is maintainable. It can locate the errors easily and changes can be identified for re-testing and modification.

Conclusions and Recommendations

After conducting series of careful tests of the system, it is concluded that the developed pollution monitoring system is usable for the target beneficiary using the specified and recommended software and hardware requirement.

The researchers further recommend follow-up study and development of the system to widen the scope and lessen the limitations of the existing and proposed system. The recommendation shall focus on the developing the device itself including the proximity, response time and capability of the device. Addition of various air pollutants is also recommended to further test its capability.

With regards to stakeholders, the researchers recommend for a funding of the government or the local municipality for the cost and implementation of the device. It is advised also that the agency impose further regulations to various factories and plants in the area and its nearby areas regarding the safety of the air in accordance to the Clean Air Act

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