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Smart Framework for Environmental Pollution Monitoring and Control System Using IoT-Based Technology

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Abstract: Nowadays, our environment is suffering from environmental pollution, especially air and sound pollution. This is on a rapid increase due to speedy growth in industrial and human activities across the universe. Therefore, a monitoring and control system is recommended to bring these pollutants under control. This paper presents an IoT-Based framework for environmental pollution monitoring and control system that can detect and monitor both the level of sound and the existence of harmful gases in the environment. The paper extended our previous conference paper work [15]. The methodology employs the use of MQ-2 gas and LMVR sound sensors and a real working prototype was designed and implemented. The Proteuos 8.0 professional and embedded C programming language are used as the development tools. The hardware architecture consists of the Arduino UNO board with hardware support packages, Wi-Fi module and a web server for monitoring pollution levels. The implemented prototype was tested for two parameters, namely, noise and smoke levels. This is achieved by comparing the threshold value with the normal behavior levels of the sensors. This process provided a real time data for monitoring and control of pollution, which make the environment smart and conducive for living. Real-time measurements of the two parameters are taken as long as the system prototype is on and connected to the internet. A Wi-Fi module was used to provide internet access and data synchronization between sensors. The sensor data can be monitored and control from remote locations via the internet. Experimental results and case study, demonstrates the flexibility and efficiency of the proposed system. These findings will help to plan for a healthy surrounding so that smart-environment users will be able to control the pollution by taking necessary measures to reduce the level of pollutants for smart environments. With the implemented device prototype, it’s very easy to monitor and control the level of air and sound pollution present in the environment.

Keywords: Internet of thing (IoT), MQ-2 gas sensor, LMVR sound sensor, Monitoring and control, Fabricated prototype, Proteus 8.5 design suite, Arduino integrated design environment.

1. Introduction

The speedy advancement in infrastructure and industrial activities has given rise to air and sound pollution in our environment. These activities are paramount importance to the human development, but they have an adverse effect to the surrounding and human health. Therefore, it is necessary to monitor and control the air quality as well as the sound intensity level to keep the environment smart. The use of sensors to sense the environmental parameters of interest is very important. In addition, the internet of things (IoT) marketing strategies, including some specific modeling techniques for improving air quality for home services is essential [1]. The deployment of IoT technology has enhanced the way we communicate not only using mobile devices, but it comprises all objects and things within our smart environment [2].

Environmental pollution is a means by which harmful and destructive substances in the environment cause adverse changes in the landscape, this can take the form of chemical substances or energy, for example smoke, noise, heat or light. Conversely, pollutants are the components of pollution. The pollutants can occur naturally or can be caused by human activities. Pollutants can be categorized into two groups, namely, primary and secondary pollutants. Primary pollutants are formed through the process of volcanic eruption. For instance, carbon monoxide gas, sulfur dioxide. On the other hand, secondary pollutants are not released directly. They are formed based on the interaction and reaction of the primary pollutants in the atmosphere [3]. Environmental pollutants can be emitted directly or formed from the interaction of other primary pollutants. Therefore, pollution is becoming a serious source of concern in smart environments. The technological development in terms of an infrastructure and industrial plants has immensely contributed to the climate change, health care challenges and environmental conditions. Therefore, an IoT–Based framework for environmental pollution monitoring and control system in a smart environment is essential [4].

In a smart environment, air and sound pollution are the major concerns. Therefore, it is very essential to monitor and control the air quality and sound level for healthy living. This paper, presents smart IoT-Based framework for air quality control and sound pollution monitoring system that provides the users with the capability to monitor and check the air quality as well as the sound pollution level in a smart environment through the use of the internet of things (IoT) technology. The framework employs the use of MQ2 gas and LMVR sound sensors. The gas sensor senses the presence of harmful gases and compounds like nitrogen oxide (NH3), Benzene, smoke and carbon dioxide (CO2) in the atmosphere and continuously transmit this data to the microcontroller unit. In addition, the system keeps monitoring and controlling the sound level and transmit the data to the online server though the Wi-Fi module. The sensors continuously sense data and communicate with the microcontroller which processes this data and transmits through the Wi-Fi module to the internet. This capability will allow the smart environment-users to monitor and control air and sound pollution in a diverse environment and to detect air quality and noise level for better living. [5-7].

Advances in science and technology have greatly influenced the protection of human health in smart environments. By way of providing a protection against the pollutants, researchers have developed approaches for monitoring and control of the environmental pollution problems [8]. The use of sensors to detects the presences of harmful gases or compounds in the atmosphere and continually transmit these data to the web server for processing, is one of the approaches to solve the pollution problem. The processed information could be used by the smart-environment users to take necessary actions for pollution monitoring and control. Pollution monitoring and control system will assist in monitoring bad air and sound pollution from our daily activities and make the environment smart [9-10].

In this research paper, a working prototype was designed and implemented using an Arduino board, sensors and embedded C programming language. The implemented prototype was tested for two parameters, namely, sound and smoke with respect to the normal behavior levels or given specifications. Thus, the prototype provides a monitoring and control over pollutants and makes the environment smart. The salient contributions of this paper are as follows:

1) To design and implement a prototype to monitor and control air quality and sound pollution level in a smart environment using IoT-Based technology.

2) To propose a solution that will enable the monitoring and control of noise and carbon dioxide (CO) levels and other harmful gases in the atmosphere using a specified or customize threshold value.

3) To provide an intelligent remote monitoring and control of an environmental pollution via internet.

The rest of this paper is organized as follows: Section 2 presents the related work; Section 3 discusses the design methodology; Section 4 discusses the experimental results; Section 5 discusses the case study; and Section 6 provides the concluding remarks.

2. Related Work

This paper presents a system that avoids complex algorithms and also minimize the use of many jumper wires during design and implementation. The gas sensor used by the previous author's works [1-10], can only detect very few gases and also have a slow response time and sensitivity. However, in this paper, the MQ2 gas sensor was used. This sensor has a wide detecting scope, i.e., it can detect many gases such as LPG, I-butane, propane, methane, alcohol, hydrogen and smoke. In addition, the sensor has fast response time and sensitivity to pollutants, is stable and has a long-life span.

The work of the authors in [1], presented an IoT marketing strategies, including some specific modeling techniques for improving air quality of home services. The study provided a summary of the current research on sensor-based home IoT indoor air quality and random sensor data generation. Furthermore, an air quality enhancement model for marketing using analytical data and spectrum density and cubic spline technique was provided. The study also provided data according to the user behavior. These data values and logic are combined into the home IoT system to provide users with simple access to the system via mobile or web-based applications. It's envisaged that the study will contribute to enhancing the improvement of the IoT home market.

The rapid development in the Internet of Things (IoT) has enhanced the way we communicate not only using mobile devices, but it comprises all things within our surroundings. Several studies have provided an insight into IoT-related services and platforms. But they failed to provide an insight into an IoT network. The authors provided a survey and technical details about IoT network. In addition, the survey provided an insight about the future IoT-network and its critical components [2].

An integration of several environmental sensor networks within the framework of the IDEA project was presented. The main aim was to measure noise and air quality, pollution levels in urban areas in Belgium, making use of a low-cost sensor. The work presented the IDEA environmental measurement cloud as a proof-of-concept. The provision of Data-as-a-Service (DaaS) cloud platform that combines environmental sensor networks with a sensor web. The DaaS platform provided an implementation of a federated two-layer architecture to lightly link together sensor networks installed over a widespread geographical area with capability of providing a web service. The service provided the means of several data access and discovery and visualization services to the public, in addition to serving as a scientific tool for noise pollution research. The service hosted 6.5 TB of environmental data and provided real-time noise pollution measurements from over forty different locations in Belgium [11-12].

3. Design Methodology

The proposed IoT-Based framework for air and sound pollution monitoring and control system consists of six units, namely, the user interface; the microcontroller; Wi-Fi module; gas sensor; sound sensor; and liquid crystal display units as shown in Fig. 1. The user interface unit provides the means by which the users can interact with the system through a personal computer (PC), or mobile devices.

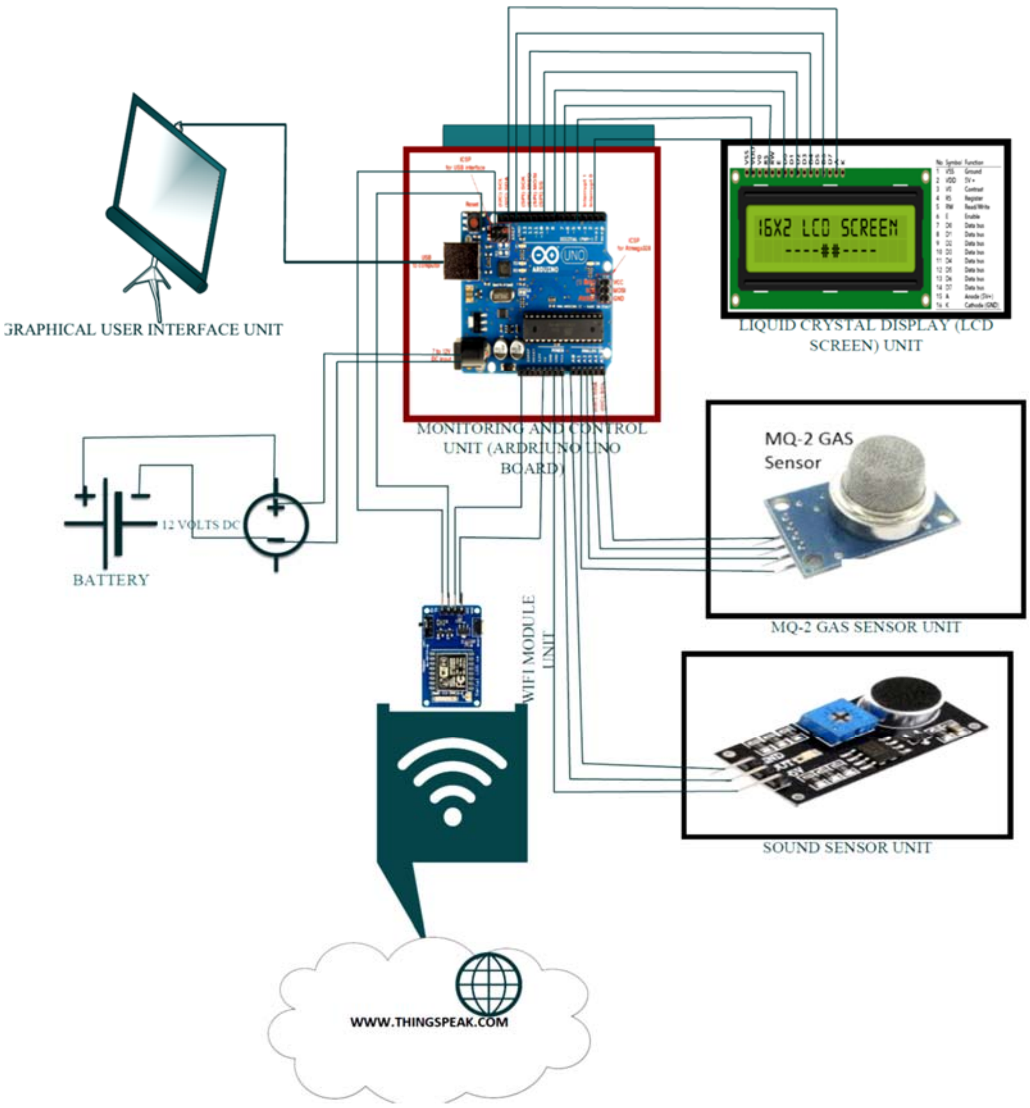

Fig. 1. An IoT-Based framework for air and sound pollution monitoring and control system.

The Arduino microcontroller unit is based on ATmega328 [13]. The microcontroller consists of 14 digital input and output connection pins. Six of the pins are used as PWM output, and another six pins are used as analog inputs. The Arduino UNO is programmed with an embedded C language using Arduino integrated development environment (IDE). The 8-bit microcontroller integrates a 32 kilobyte ISP flash memory with read-while-write capabilities. Other components include: one kilobyte EEPROM; two kilobyte SRAM memory; twenty-three general purpose input / output lines; thirty-two general purpose working registers; three flexible timer / counters with compare modes; internal and external interrupt controller, programmable universal synchronous / asynchronous / Receiver / Transmitter (USART). The Wi-Fi module unit provides the functionality of uploading the sensor reading to the webserver for analysis. The gas sensor unit provides a wide sensing and detecting scope, the sensor can detect many gases such as LPG, I-butane, propane, methane, alcohol, hydrogen and smoke. In addition, the unit has a high sensitivity and response time. The sensor's output is an analog resistance and operates at temperatures between -20 ^oC to 50 ^oC degrees centigrade.

The sound sensor module provides a means to detect sound and its intensity. This unit has a microphone which supplies the input to an amplifier, peak detector and buffer. When the sensor picks a sound, it transmits an output signal voltage to a microcontroller unit. The liquid crystal display unit displays the processed sensor data from the microcontroller to users for necessary actions [14-16].

3.1. System Flowchart

Fig. 2 illustrates the system flow chart for an IoT-based air and sound pollution monitoring and control system. The system works as depicted in Fig. 2. A dedicated connection is established between the sensors, Wi-Fi module and the microcontroller. The sensed data from the two sensors are pre-processed by the microcontroller before transmission to the webserver. An AT commands will be initiated and send to the Wi-Fi module to transmit the pre-processed data to the webserver for further data analysis and visualizations. The status of the Wi-Fi module will be checked regularly to ensure availability and reliability of the network connectivity. If at anytime, the status of the Wi-Fi and webserver connection is found to be not connected, then a connection reset should be made. The transmitted data from the Wi-Fi module to the web server will now undergo data analysis and visualization. Once the device is switched on, the microcontroller will start processing data over the Internet. By using a wireless hotspot access point, users can access internet browser on their smartphones or laptops. The Web browser needs specific IP address of the web server to access the processed information. By putting the IP address on browser, a web page is displayed (www. thingspeak.com). The Web page will display the processed results of the air and sound pollution monitoring and control system.

3.2. System Simulation

Fig. 3 illustrates the schematic layout of the proposed IoT based framework and how the various components of the system are interconnected. The outputs of the two sensors are connected to the analog input pins of the Arduino microcontroller which serve as an interface, this provides a dedicated communication between the sensors and the microcontroller unit. The LCD screen displays the processed data from the two sensors. The simulation was performed using Proteus professional design tool [17]. As can be observed, the simulated system displays the smoke level and the status of the surrounding air quality on the liquid crystal display (LCD) screen. Fig. 4 demonstrates the workability of the implemented prototype.

4. Experimental Results

The experiment was conducted using the designed prototype. Several results were collected and analyzed. The system was tested with different levels of sound and smoke, the expected output was found to be accurate. The monitoring and control of the sound and gas sensors was possible through a personal computer (PC) or a smart phone. The Wi-Fi module transmits the sensed data to an IoT-Based internet website called thingspeak.com.

The results obtained in this paper are the output from the two sensor readings based on two scenarios. In the first scenario, the device prototype was ran and tested with different kinds of pollutants, such as smoke from cigarettes, smoke from a kerosene stove and also sound coming from a mobile phone. In the second scenario, the system was tested with smoke and sound coming from a motorbike and car exhaust. The measurements are categorized into two parameters viz; gas and sound together with the date and time in which they were sensed and captured as illustrated in Fig. 5 and Fig. 6 respectively.

4.1. Sensor Data Logging

Each sensor sends data to the Arduino board which transmit it to the Wi-Fi module. The Wi-Fi module then communicates the data to the internet for real time monitoring. The data received during the testing period for the months of January and June are illustrated in Fig. 5 and Fig. 6 respectively.

4.2. Sensor Data Monitoring and Control via the Internet

Fig. 7 and Fig. 8 illustrate the monitoring and control system's data analysis for gas and sound pollution. The processed sensor data are transmitted through the Wi-Fi module to the internet and display on the thingspeak.com website. As can be observed, the sensor data for the air and sound pollution are analyzed, visualized and presented. The user can analyze it with the help of the plotted graphs. The plotted graphs make it very easy to verify the levels of air and sound pollution in a smart environment and plan for a healthy living.

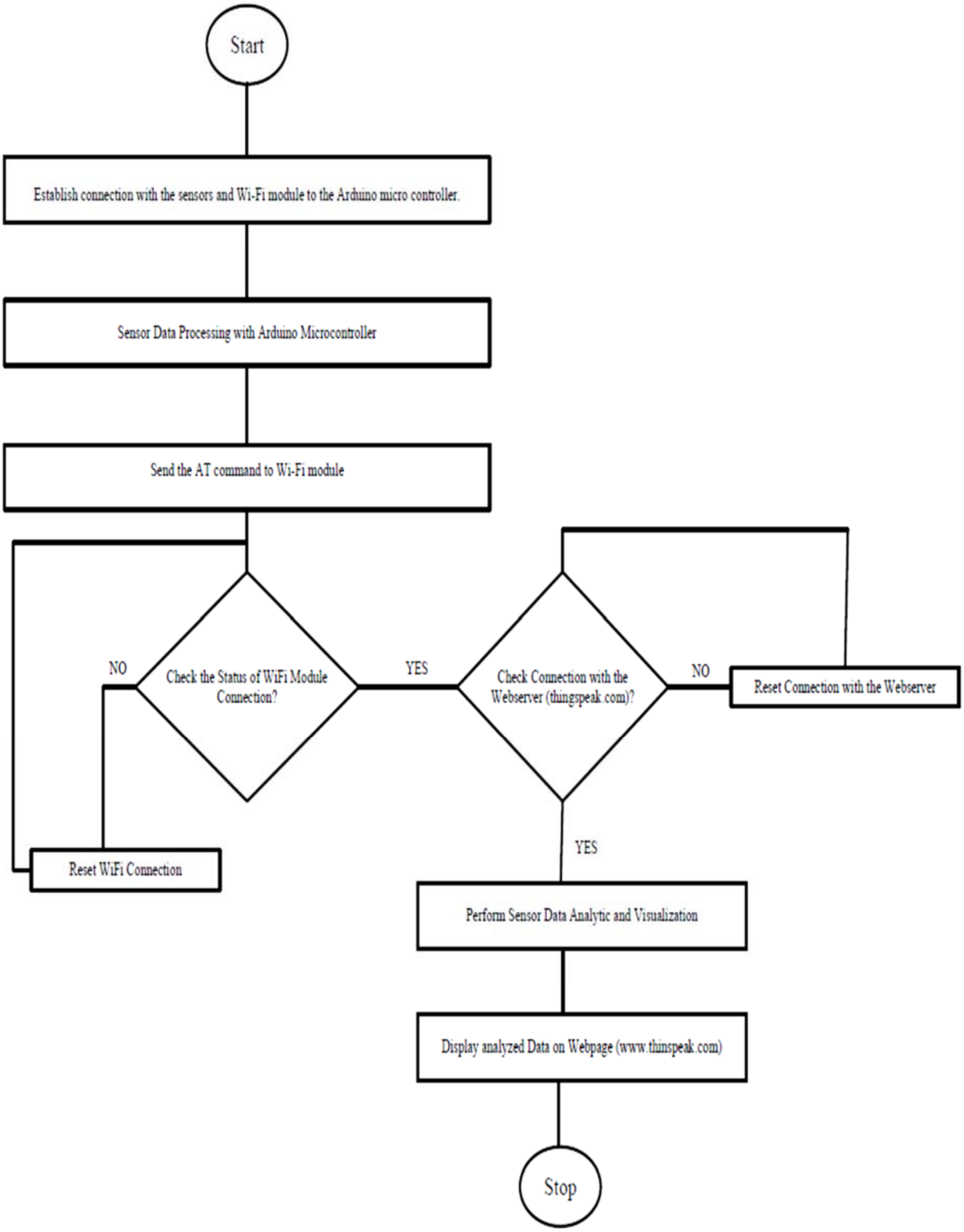

Fig. 2. System Flowchart for the IoT-Based framework for air and sound pollution monitoring and control system.

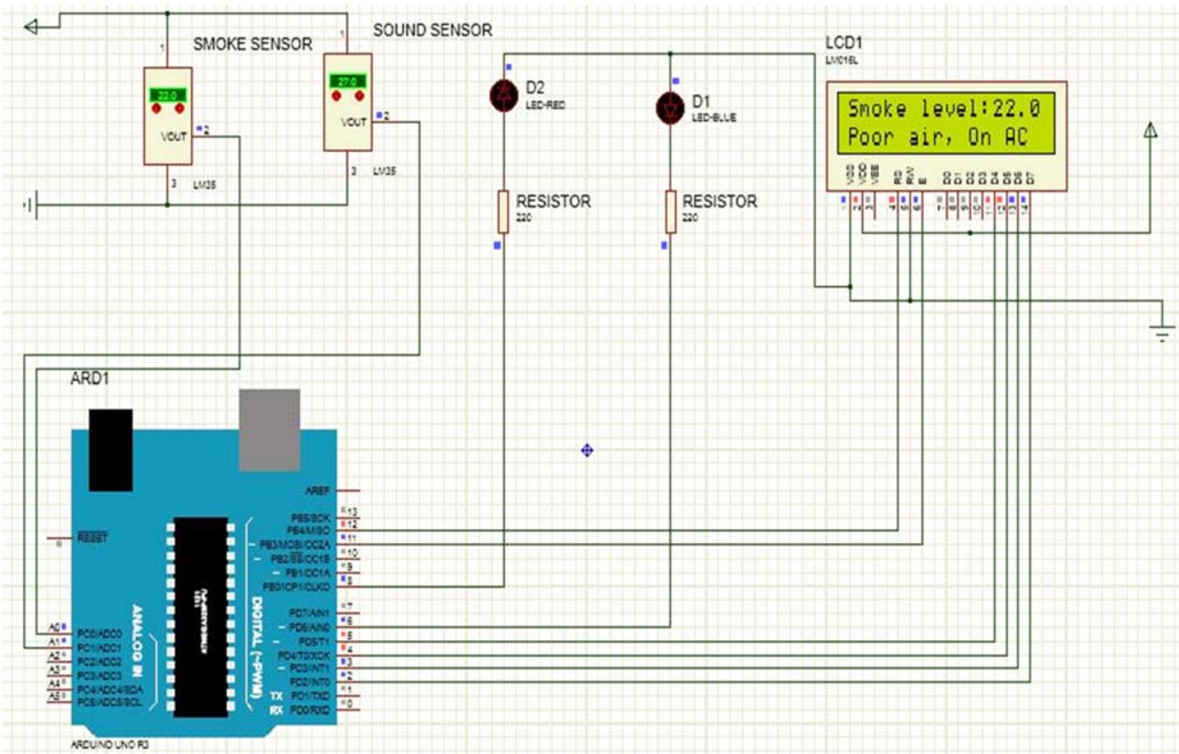

Fig. 3. Schematics Block Design of An IoT-Based framework for air and sound pollution monitoring and control system.

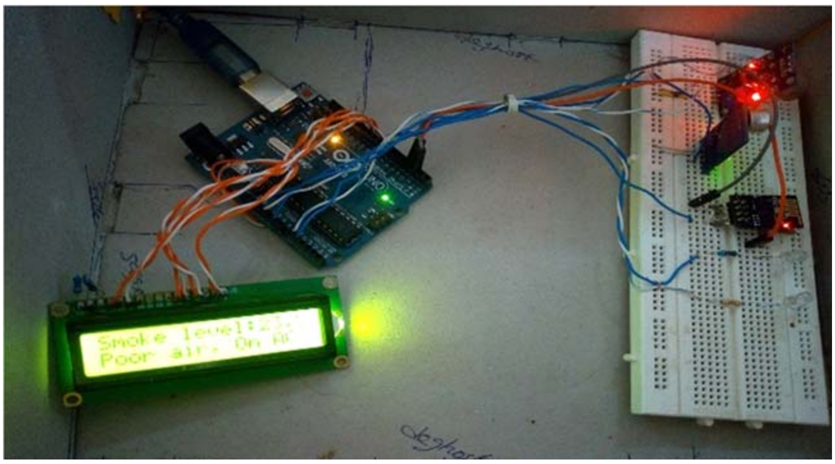

Fig. 4. The implemented prototype.

1	Date_of_Captured_Sensor_Data	Entry_ID	Gas_Sensor_Readings	Sound_Sensor_Readings
2	2018-01-12 09:58:59 UTC	477	4.4	19.06
3	2018-01-12 09:59:14 UTC	478	4.4	19.06
4	2018-01-12 09:59:29 UTC	479	4.89	19.06
5	2018-01-12 09:59:45 UTC	480	4.89	19.06
6	2018-01-12 10:00:00 UTC	481	5.38	19.55
7	2018-01-12 10:00:17 UTC	482	4.89	19.06
8	2018-01-12 10:00:39 UTC	483	4.89	19.06
9	2018-01-12 10:00:54 UTC	484	4.89	19.06
10	2018-01-12 10:01:10 UTC	485	4.89	19.06
11	2018-01-14 17:27:50 UTC	486	26.25	19.06
12	2018-01-14 17:28:23 UTC	487	29.33	20.04
13	2018-01-14 17:28:45 UTC	488	23.46	19.55
14	2018-01-14 17:29:05 UTC	489	18.57	19.06
15	2018-01-14 17:29:20 UTC	490	16.62	19.06
16	2018-01-14 17:29:44 UTC	491	14.66	20.04

Fig. 5. Data logged for air and sound pollution for the month of January 2018.

	Date_of_Captured_Sensor_Data	Entry_ID	Gas_Sensor_Readings	Sound_Sensor_Readings
2	2018-07-31 14:07:29 UTC	500	31.28	20.53
3	2018-07-31 14:07:47 UTC	501	25.42	20.53
4	2018-07-31 14:08:09 UTC	502	23.46	21.99
5	2018-07-31 14:08:31 UTC	503	30.3	21.99
6	2018-07-31 14:08:52 UTC	504	21.51	21.99
7	2018-07-31 14:09:14 UTC	505	29.33	21.51
8	2018-07-31 14:09:29 UTC	506	20.04	20.53
9	2018-07-31 14:09:46 UTC	507	28.73	20.53
10	2018-07-31 14:10:08 UTC	508	30.3	21.51
11	2018-07-31 14:10:29 UTC	509	20.53	21.99
12	2018-07-31 14:10:52 UTC	510	19.55	20.53
13	2018-07-31 14:11:10 UTC	511	19.55	21.99
14	2018-07-31 14:11:43 UTC	512	16.62	21.99
15	2018-07-31 14:11:59 UTC	513	14.17	20.53
16	2018-07-31 14:12:14 UTC	514	14.17	20.53
17	2018-07-31 14:12:30 UTC	515	14.66	21.51
18	2018-07-31 14:12:45 UTC	516	14.17	21.99
19	2018-07-31 14:13:08 UTC	517	13.69	21.02
20	2018-07-31 14:13:36 UTC	518	13.69	21.51
21	2018-07-31 14:14:12 UTC	519	14.17	21.51
22	2018-07-31 14:14:28 UTC	520	13.69	21.99
23	2018-07-31 14:14:43 UTC	521	12.22	20.53
24	2018-07-31 14:15:06 UTC	522	12.22	21.02
25	2018-07-31 14:15:29 UTC	523	12.22	20.53
26	2018-07-31 14:15:44 UTC	524	12.22	20.53
27	2018-07-31 14:16:00 UTC	525	12.22	20.53
28	2018-07-31 14:16:15 UTC	526	11.73	20.53
29	2018-07-31 14:16:38 UTC	527	13.2	21.99
30	2018-07-31 14:16:54 UTC	528	12.71	21.51
31	2018-07-31 14:17:14 UTC	529	11.73	20.53

Fig. 6. Data logged for air and sound pollution for the month of June 2018.

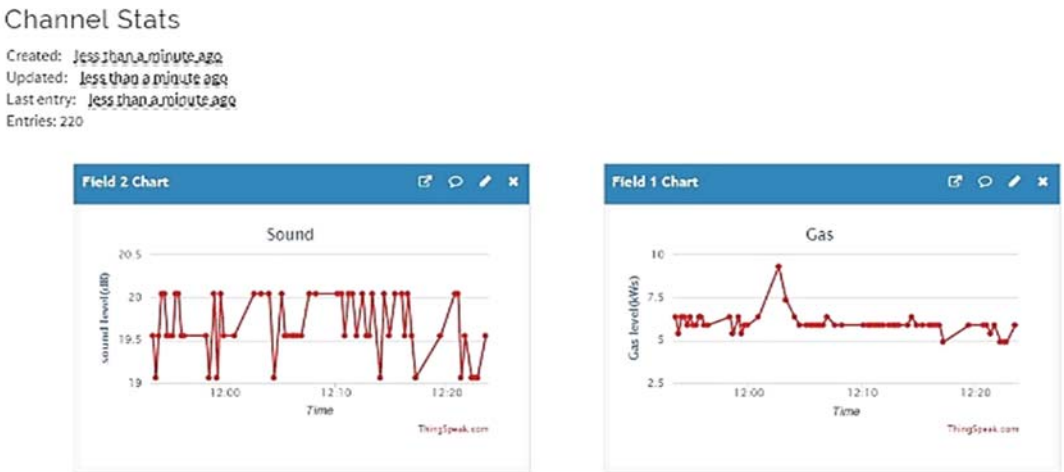

Fig. 7. Variations of gas and sound pollution with respect to time.

5. Case Study

This paper presents a case study to demonstrate the efficiency and flexibility of the proposed system. The results obtained in this section are based on three scenarios and different pollution sources. In the first scenario, the device prototype was tested with pollution source coming from kerosene stove and sound from a mobile phone. In the second scenario, the system was tested with smoke and sound coming from a motorbike. In the third scenario, the device is tested with smoke and sound coming from car exhaust. Fig. 9 to Fig. 11 illustrate the variation of pollutants with respect to counter values.

Fig. 9 shows the variations of sound and gas pollution from kerosene stove and mobile phone sources. As can be observed, the sound pollution level coming from the mobile phone is higher as compared with smoke level from the kerosene stove. The sound pollution was stable at initial counter values from (0 to 49) with a decibel of approximately 13 dB. The sound pollution level rises up gradually and attain its value of 17 dB and became stable. In contrast, the smoke from the kerosene stove is unstable, it fluctuates i.e., rises and falls due to the characteristic nature of the burning fuel and the atmospheric air. The smoke rises to highest level as far as the stove continues to burn the kerosene fuel with respect to the increasing counter values.

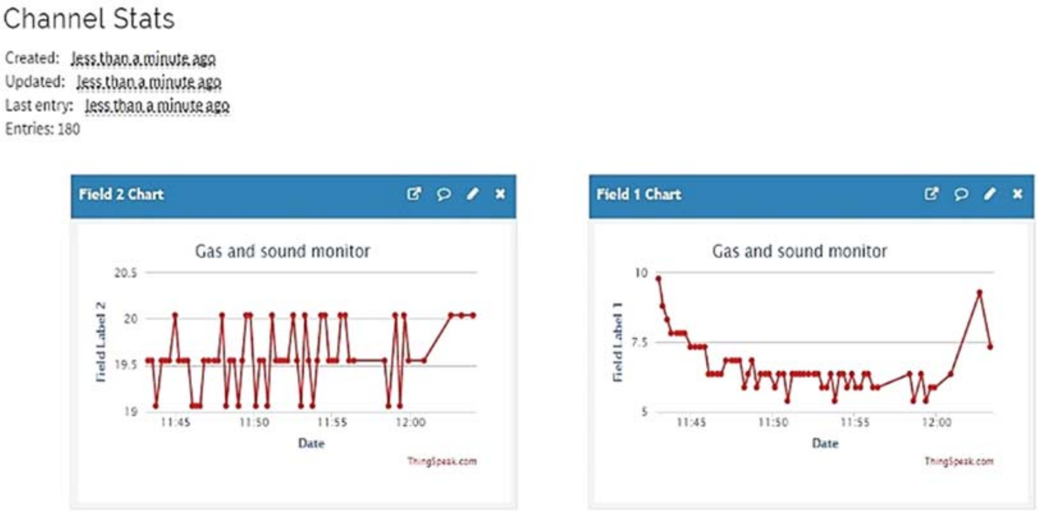

Fig. 8. Variations of gas and sound pollution with respect to time.

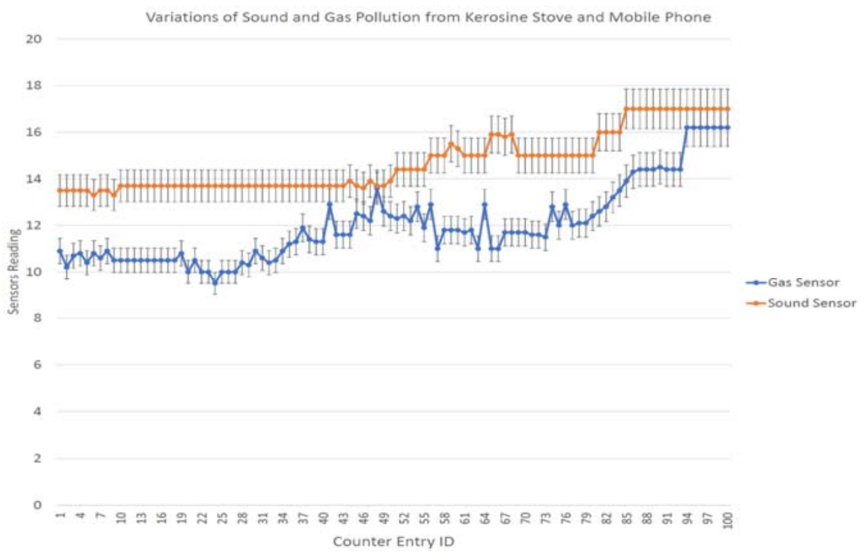

Fig. 9. The variations of sound and gas pollution from kerosene stove and mobile phone sources.

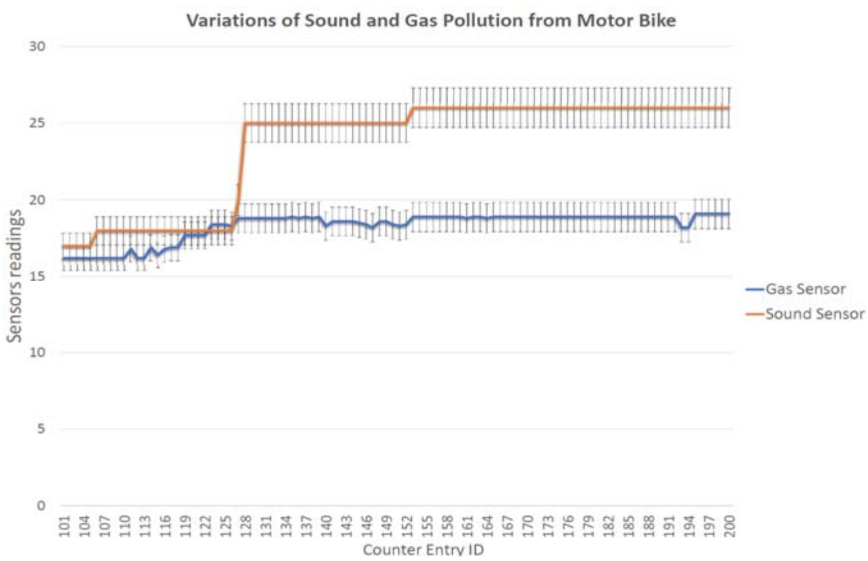

Fig. 10. The variations of sound and gas pollution from a motorbike as a source.

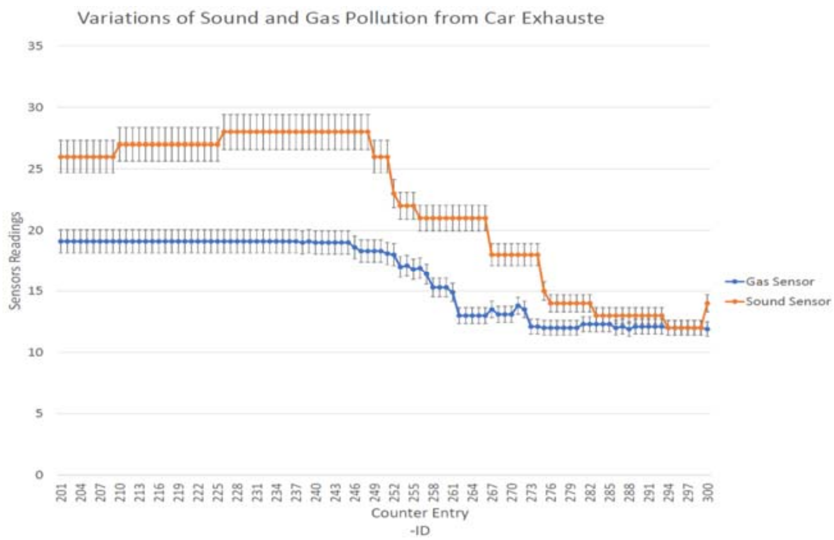

Fig. 11. The variations of sound and gas pollution from car exhaust engine.

Fig. 10 illustrates the variations of sound and gas pollution from a motorbike as a source. In this scenario, we can observe a slight variation from the pollution source. The sound pollution spread linearly with a decibel of 19 dB. The sound then rises up from 25 dB to 27 dB and became stable. In contrast, the characteristics of the smoke coming out from the motor bike exhaust engine (silencer) exhibit a linear gas pattern. The smoke spread linearly and gradually spikes up to a value of 18 dB and became linear and stable. The smoke continued to be linear and stable over long ranges of counter readings.

Fig. 11 shows the variations of sound and gas pollution from car exhaust engine. In this scenario, we can observe a significant rise in the sound noise level up to 28 dB. This is due to the sound intensity emanating from the car exhaust engine. The sound then slightly decreases to below 15 dB when the engine slowly goes down. The smoke coming from the exhaust engine (silencer) followed a similar pattern compared with sound. The smoke spread linearly in high volume compared with the smoke from motor bike and goes down drastically as the engine is slowly going down. The smoke coming from the car exhaust depends on the engine quality and the quality of fuel used. These findings will help the smart home users to be kept informed about the level of air and sound pollution in their environment so that appropriate precaution measures can be taken for sustainable development.

6. Conclusion

This research paper used the capabilities of two sensors, namely, the MQ-2 gas sensor uses to detect the gaseous level in the environment and LMVR sound sensor which is used to detect sound coming from different sources. The proposed system provides an efficient and low-cost solution to environmental pollution monitoring and control. The Micro controller reads the inputs from the sensors and turns it into an output which is displayed on the liquid crystal display (LCD) screen. The data detected by the sensors, are communicated to the internet via the Wi-Fi module. The methodology used in this work was to collect data from the sensors, display it on the webpage, analyze and monitor the environmental pollution levels. The system was tested and monitored on three different scenarios with different sources of pollutants. Experimental results and case study demonstrated the efficiency and flexibility of the proposed system. The developed system will help the smart-environment users to discover how a little smoke or noise can alter the natural balance thereby leading to environmental pollution. The proposed system can be extended to monitor and control air and sound pollution in developed cities, industrial areas and public health-care centers for sustainable development.

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