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Arduair: Air Quality Monitoring

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Abstract

Air pollution and quality monitoring is extremely important in today's world as it has a direct impact on human health. Air pollution is on the rise due to a number of anthropogenic activities and its monitoring is of vital importance to mitigate certain measures to control it. In this paper we put forward a low-cost and low-power sensor based system for air quality monitoring. This sensor based system is in contrast to traditional stationary air pollution monitoring stations as we present the design, implementation and working of ArduAir, a small and portable measurement system that is based on low-cost sensors and microcontrollers and can be commercially used by a number of people. The data from the sensors on ArduAir can be collected from various places and be stored, plotted graphically and easily updated. Vital to the success of sensing applications is the high quality data from the sensors of ArduAir. The data collected by the sensors on ArduAir is then plotted in real-time on a computer and can be stored. Finally we compare the data from ArduAir of a region with the data of 'Delhi Pollution Control Committee', Kashmere Gate, Delhi.

Keywords: Arduino, Gas sensor, air pollution monitoring, real-time data plotting, serial communication and interfacing.

1. Introduction

Air pollution is a major concern in modern cities and in developing countries nowadays. Atmospheric pollutants such as CO_2, NO_2, CO, O_3, SO_2, Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM) and Volatile Organic Compounds (VOCs) have a direct impact on the human health; they are responsible for a variety of respiratory illnesses (such as asthma) and can cause cancer in humans if they are exposed to these pollutants for extended periods of time. As an instance, carbon monoxide is highly toxic to humans as it can cause severe headaches, asphyxiation due to formation of carboxyhemoglobin and even death if exposed for prolonged time. Also these pollutants are responsible for many environmental problems such as acid rain and ozone layer depletion. Hence, air pollution monitoring is vital nowadays especially in the urban and industrial areas.

Air quality monitoring by monitoring stations. Nowadays, air pollution is monitored by static air quality measurement stations that are operated by official authorities. These stations are highly reliable and can measure the pollutants in air to a high level of accuracy and precision using analytical instruments, such as mass spectrometers. However, extensive cost of acquiring and operating such stations limits the number of installations.

Air quality monitoring by *ArduAir*. The concentration of air pollutants such as CO_2, CO, SO_2, etc. is highly location-dependent. The urban areas with heavy traffic concentration and industrial areas have a considerable impact on the local air pollution. Since the air pollution monitoring stations are costly and so are limited in number, we have come up with *ArduAir* which is a small and portable measurement system which includes various gas sensors (such as CO, CO_2, NO_2, O_3, etc.) and microcontroller that can be used by a number of people. We have also devised a software for collecting the data from the *ArduAir* and plotting it in real-time. Thus *ArduAir* can provide the user with:

- Low-cost and low-power measurement hardware that is suitable for mobile measurement;
- User-friendly data collection and processing software;
- Gathering high quality data;
- Easy to use instrument that can be used commercially by a large number of people.

We connect a small-sized, low-cost CO sensor to an arduino microcontroller module which is then connected to a computer via serial communication. The data collected by the arduino microcontroller from the sensor will then be sent to the computer software where it gets recorded and plotted in real-time. We describe in Sec. 2 the hardware and software system designs in detail. Also the real-time data plotting software is discussed in Sec. 2 in detail. In Sec. 3, we describe the conventional technique followed by air quality monitoring stations for monitoring of carbon monoxide. In Sec. 4, the data collected from the ArduAir system is validated and compared with the data from Delhi Pollution Control Committee. This sensor based system can be used easily by a large number of people and would thus contribute to monitoring air quality in the society.

2. System Design

This section describes the hardware and software components and architecture of ArduAir.

2.1 Hardware

Our measurement system consists of three parts as shown in Fig. 1(a). We use MQ5 sensor module from EleSof Technologies [1] to sense the carbon monoxide (CO) concentration in the atmosphere making use of the measured resistance of the sensor's tin dioxide (*SnO_2*) layer. Digital communication is possible over the board's RS232 interface. The Arduino Uno [2] board is connected to the MQ5 gas sensor module as shown in Fig. 1(a) and connected via USB to a computer system for logging real-time data from the sensor. All the parts of ArduAir including the sensor module and arduino are easily available at low prices. This is essential to obtain widespread acceptance of the air pollution monitoring system.

2.1.1 Sensor module connections

MQ5 gas sensor module is connected to the arduino Uno board using jumper wires. The Analog pin on the sensor is connected to the analog pin 0 on the arduino board, while the +5V and GND pins on the sensor module are connected to the 5V Vcc and GND (ground) pin respectively on the arduino board. The arduino Uno board is then connected to a computer system using USB connection and RS232 interfacing.

2.1.2 Gas Sensor working principle

Fig. 1(b) illustrates the working principle of a gas sensor such that when a metal oxide crystal such as SnO_2 is heated, gas is adsorbed on the crystal surface with a negative charge. Then the donor electrons in the crystal surface are transferred to the adsorbed oxygen that results in leaving positive charges in a space charge layer. Thus, a surface potential is formed to serve as a potential barrier against the electron flow. Inside the sensor, current flows through the grain boundary (conjunction parts). At conjunction parts, adsorbed oxygen forms a potential barrier which prevents the carriers from moving freely. The reduced barrier height thus decreases sensor resistance.

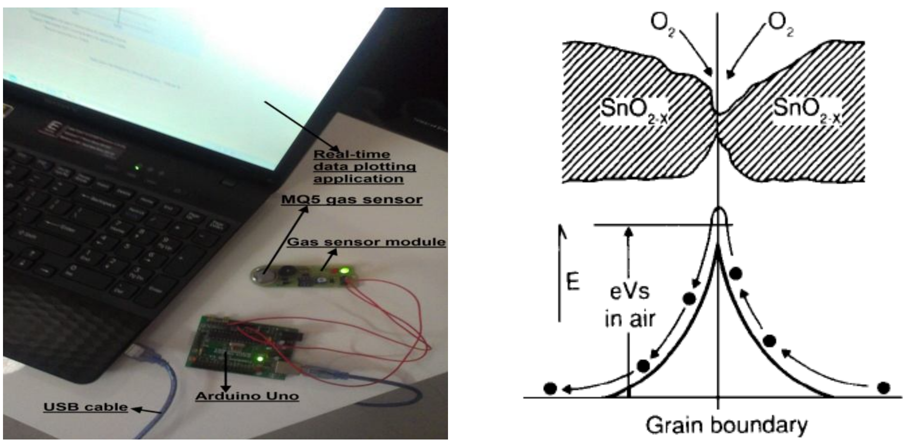

Figure 1. (a): ArduAir hardware.

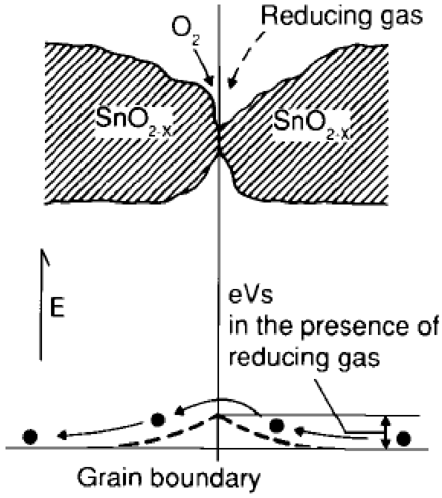

Figure 1. (b): Gas sensor working principle.

From Ohms Law, voltage value is directly proportional to the current and resistance value in the circuit. Therefore, as the sensor detects higher gas level concentration, resistance value in grain boundary will increase. As the resistance increases, the output voltage will also be increased.

2.2 Software

The software of ArduAir system includes the coding of the Arduino Uno board in its Integrated Development Environment (IDE) also known as Arduino IDE and developing the real-time data collection and plotting application in Microsoft Visual Basic 2010 Express [3]. The serial communication between the arduino, sensor and the computer system was established using the serial library of the arduino. The concentration of the gas measured depends upon the resistance of the gas sensor which further depends on the voltage of the analog output pin of the sensor. The sensor returns an analog voltage to the arduino which is converted to resistance and then using the relation derived from the curve in Fig. 2(a), the concentration of the gas is measured in micro grams per cubic meter ($\mu g/m^3$). The equations derived for converting the measured voltage to gas concentration are:

$$Vrl = Va * (5.00 / 1024.0) \quad (1)$$

$$Rs = 20000 * (5.00 – Vrl) / Vrl \quad (2)$$

$$\text{Concentration (in } \mu g/m^3) = 37143 * [(Rs/Ro)^\wedge\text{-}3.178] \quad (3)$$

Where Va represents the analog output send by the sensor to arduino and Vrl is the equivalent voltage from the analog output (in volts). Rs is the sensor resistance at various concentrations of gases and also at different temperatures and humidities. Then the concentration of CO gas can be calculated by Eq. (3) which is derived from the curve in Fig. 2(a). Here, Ro = 10000 Ω which is the load resistance or sensing resistance used for calibration of the sensor and for its sensitivity adjustments.

The real-time plotting application developed in Microsoft Visual Basic 2010 Express is shown in Fig. 2(b). Real-time data was taken from the sensor interfaced with arduino and was fed via USB or serial communication to the computer application. The sensor was first calibrated in an environment without CO gas and then was used for its detection. The readings for CO gas concentration remain stable at around 592.58 μg/m^3. A spike in the readings in the plot is observed when a matchstick is lighted near the sensor and is then extinguished which results in a release of gases like CO_2 and CO. The Y-axis indicates the CO gas concentration (in μg/m^3) and the X-axis indicates the time of operation of ArduAir (in seconds) in Fig. 2(b).

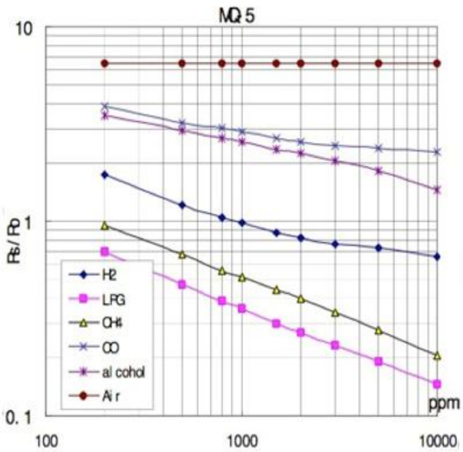

Figure 2. (a)

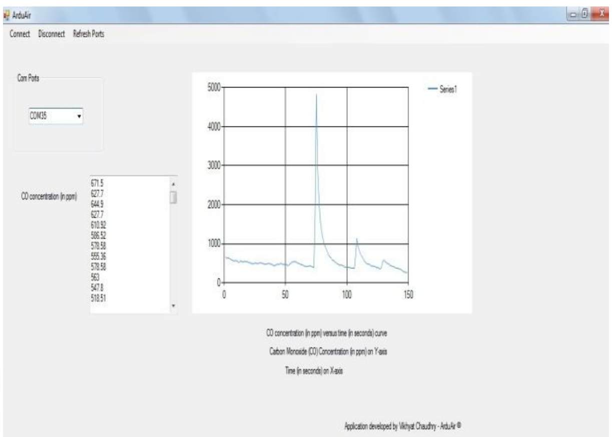

Figure 2. (b)

Figure 2: (a) MQ5 gas sensor datasheet curve for values of Rs/Ro at different concentrations of various gases (b) Real-time data plotting application for ArduAir showing the readings of CO gas in real-time. On Y-axis, Carbon Monoxide concentration in μg/m^3 and on X-axis time of operation of ArduAir (in seconds).

3. Conventional Carbon Monoxide Measurement Technique

Carbon monoxide is conventionally measured by air pollution monitoring stations using non-dispersive infrared (NDIR) spectroscopy. In NDIR based ambient CO analyzers, the spectrometer measures the absorption of CO at 4.7 μm. Some of these analyzers use different cells for standard reference gas and sample gas. Some others use gas filter correlation to compare the IR absorption spectrum between the measured gas and other gases present in the sample, in a single sample cell.

4. Validation of Sensor Data

ArduAir was operated near Punjabi Bagh region in Delhi, India to collect the readings of the concentration of Carbon Monoxide in air. The real-time readings obtained from ArduAir are tabulated in Table 1 given below. The readings obtained are then validated by using the data of 'Delhi Pollution Control Committee', Kashmere Gate, Delhi [4]. We compare and validate the real-time readings of ArduAir of Punjabi Bagh region in Delhi with that of 'Delhi Pollution Control Committee' (DPCC) and also with the permissible limits of Carbon Monoxide. The permissible limit for CO concentration for Delhi region as per DPCC and CPCB [5] is 4 mg/m^3 and the concentration obtained from ArduAir is 592.58 $\mu g/m^3$ or 0.59258 mg/m^3, which is well within the permissible limit and is hence valid.

Table 1: Real-time Carbon Monoxide concentration data measured by ArduAir.

Time (in seconds)	**CO concentration (in $\mu g/m^3$)**
0	671.5
2	627.7
4	644.9
6	627.7
8	610.92
10	586.52
12	578.58
14	555.36
16	578.58
18	563
20	547.8
22	518.51
	Average= 592.58 $\mu g/m^3$

5. Conclusion

We have shown the construction and working of ArduAir which is a small, portable and low-cost air pollution monitoring system. This system can be used easily at a large scale and domestically by a large number of people. We used ArduAir to monitor Carbon Monoxide concentration of an area and collected the data for the same. This sensor based system can also be used for various other gases such as SO_2, NO_2, CO_2, O_3, etc. using different sensors. This system can thus be utilized effectively by the general public for monitoring the quality of air around them.

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