A Low Cost Air Quality Monitoring Sensor System with Arduino Uno Micro Controller Board on Smart Phone and Laptop

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Abstract: Due to increased awareness of environmental protection and health, people set a high value on air pollution in their lifestyle; it meets urban air quality control. This paper extremely focuses on the development of a new and simple device based on Arduino and smart phone interface that is suitable to detect and measure carbon monoxide, carbon dioxide and ammonia gases in an environment. This device can also measure humidity and temperature in the outer atmosphere. The sensor node is based on Arduino UNO board, MQ–135 gas sensor, DHT–11 sensors and receiving the data from the sensors via smart phone and Laptop. This is especially significant for developing novel commercial low-cost sensors to detect and measure and monitor green house gases in the atmosphere continuously.
Keywords: Arduino UNO microcontroller board; MQ–135 gas sensor, DHT–11 sensors; Air quality monitoring.

1 INTRODUCTION

The poor air quality may start health problems such as fatigue and nausea as well as severe respiratory diseases, heart disease, and lung cancer [1, 2]. To check the quality of air is difficult for human beings either by feel or sense. So, people cannot recognize the activities done by them may create air pollution so by which air quality may degrade. By taking simple precautions people can avoided air pollution by recognizing the quality of the surrounding air they live [3]. Even though the development is made on the integrated sensor network, some problems with practice surfaces here: fixed type with many technical obstacles, such as the transfer of autonomously and real-time monitoring limits, and many uses and placement hassles [4-7]. Few researchers make use of a fixed point arrangement and movable monitoring approach, but can not achieve a truly independent movable detection system [8, 9]. Nowadays, some researchers studied the air quality monitoring in the environment using microcontrollers. The development of sensor technology is investigated [10, 11]; the sensor with the benefits of small size, high sensitivity and low cost is gradually applied in the field of embedded systems.

The MQ–135 air quality monitoring sensor is used for monitoring greenhouse gases, humidity and temperature with Arduino UNO micro controller board which is a low power, cheaper, highly flexible with ATmega328p microcontroller is designed [12]. It's a great platform for interfacing with many devices like laptops, Smart phones at the same time. The integrated wireless sensor network system transmits data based on wireless communication using Bluetooth module technology, and performs

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real-time monitoring by integrating a PC client's quality monitoring system and elevated terminal. The smart phone is connected to HC–05 via Bluetooth by entering a security password. HC–05 is used as a master when it transmits cell sensor status and as a slave when receiving instructions from mobile. In this paper we are monitoring real time gases such as CO, CO_2, NH_3, relative humidity and temperature at the same time via an integrated Arduino UNO Microcontroller board interfaced with laptop and smart phone.

2 DESIGN AND EXPERIMENTAL DETAILS

2.1 Architecture

The Fig. 1 illustrates the block diagram of a smart phone and Arduino based sensor system for air quality monitoring. The microcontroller receives the signal from MQ–135 and DHT-11 sensors transmit the data to laptop using USB and PLX–DAX and smart phone through HC 05 Bluetooth Module.

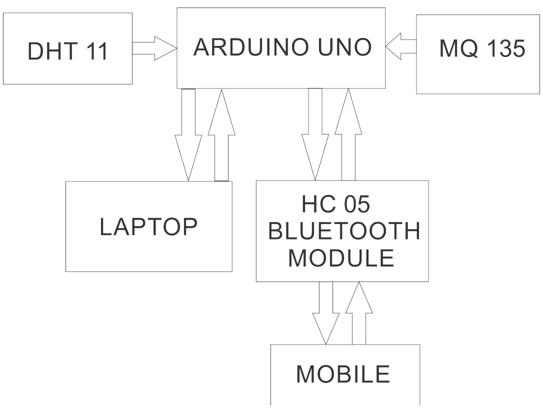

Fig. 1: Block Diagram of a Smart Phone and Arduino Based Sensor System for Air Quality Monitoring

2.2 Arduino UNO Microcontroller Board

Fig. 2 illustrates Arduino UNO microcontroller board as a platform for open source hardware and software. The Arduino UNO consists of ATmega328p microcontrollers. Arduino hardware is programmed in a wired language (syntax and library), such as C++ with minimal modification and a combined processing environment. It allows communication between computers through programming. It receives the input signal from the sensor, and then generates the output voltage displayed by the numbers displayed by the digital display [13].

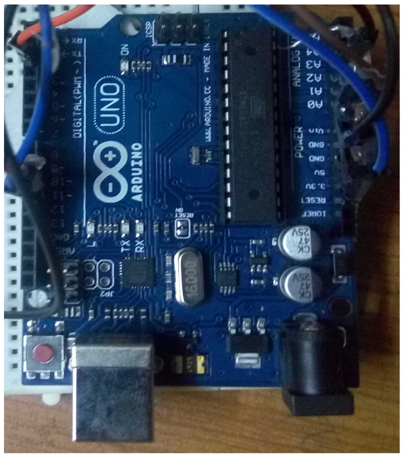

Fig. 2: Arduino UNO Microcontroller Board

The development environment of the Arduino project, or integrated development environment (IDE), is a free download for Windows operating systems. Fig. 3 demonstrates the open-source Arduino Software –Integrated Development Environment (IDE) for programming Arduino UNO. The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software.

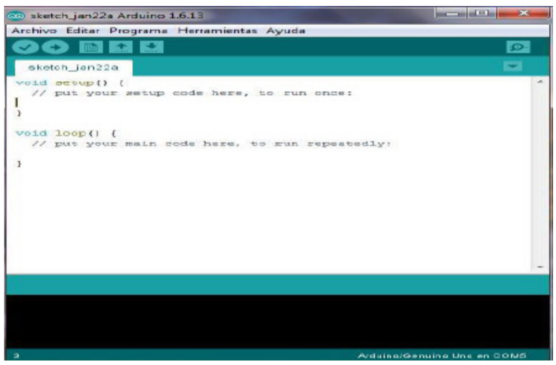

Fig. 3: The Open-source Arduino Software –Integrated Development Environment (IDE) for Programming Arduino UNO Board

2.3 DHT-11 Sensor (Digital Humidity and Temperature)

DHT-11 sensor depicted in Fig. 4 is a low cost sensor for measuring temperature and humidity, calibrated with digital output. Fig. 5 demonstrates circuit diagram of DHT-11 sensor (digital temperature and humidity) with Arduino UNO board. The sensor consists of a variety of moisture resistant and high-quality 8-bit microcontroller, providing excellent quality, quick response, compatibility and cost-effectiveness [14]. The DHT-11 sensor has 3 pins (VDD, DATA, GND). The DHT-11 sensor digital signal out pin (DATA) is connected to Arduino UNO digital pin 2 (PD2/INTO).

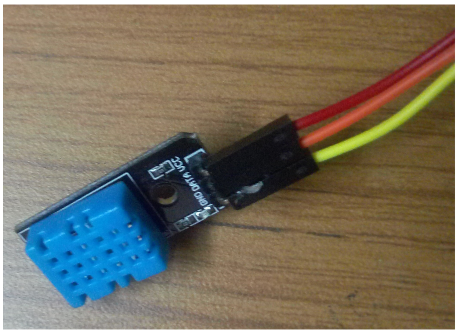

Fig. 4: DHT-11 Digital Temperature and Humidity Sensor

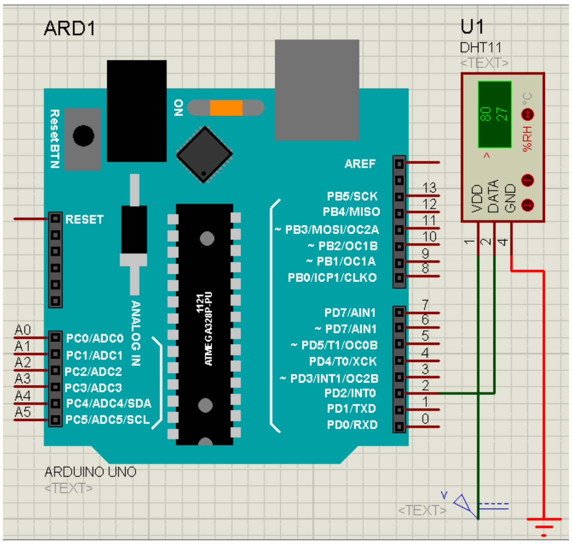

Fig. 5: Circuit Diagram of DHT-11 Digital Temperature and Humidity Sensor with Arduino UNO Board

2.4 MQ–135 Gas Sensor

MQ–135 gas sensor has extensive range for detection of CO, CO_2, and NH_3 etc., in the environment with a very low response time. MQ–135 gas sensor depicted in Fig. 6 is a low cost sensor for measuring CO, CO_2, and NH_3 gases. The MQ–135 gas sensor has 4 pins (VCC, A0, D0, GND) but only 3 pins (VCC, A0, GND) are used. VCC on MQ–135 sensor is connected to 5V of Arduino UNO board, A0 is connected to analog pin A3 on Arduino, while GND is connected to GND of Arduino UNO board. Fig. 7 demonstrates circuit diagram of MQ–135 gas sensor with Arduino UNO board.

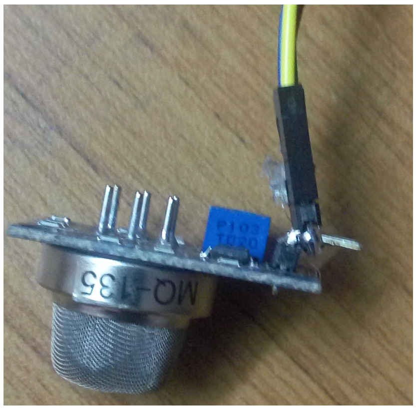

Fig. 6: MQ–135 Gas Sensor

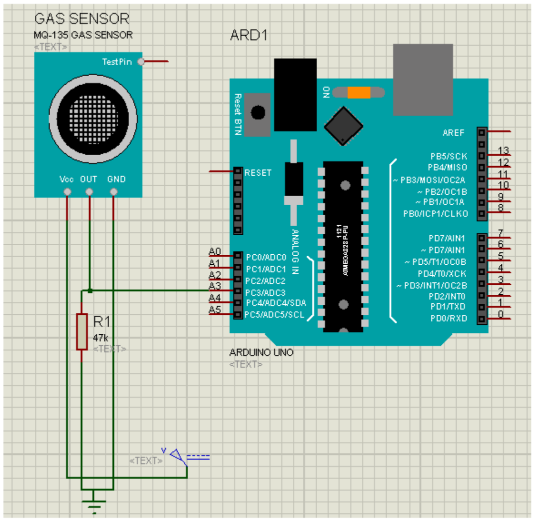

Fig. 7: Circuit Diagram of MQ–135 Gas Sensor with Arduino UNO Board

2.5. MQ–135 Gas Sensor Calibration for Obtaining Concentration of NH_3, CO_2 and CO Gases

The load resistance RL is kept at 47 KΩ for getting better results in the circuit diagram (Fig. 7). From the data sheet of MQ–135 gas sensor slope and intercept values are calculated for NH_3, CO_2 and CO gases for obtaining concentration of gases in ppm

From the data sheets it was observed that the value on X-axis which is equal to Rs/Ro=3.6, where Rs is the resistance of sensor in the presence of gas and Ro is the resistance of sensor in the presence of clean air. Sensitivity of the gas sensor Rs/Ro=3.6, Resistance of the sensor in the presence of gas R_s=V_c/V_RL X R_L, where VC = +5 V, RL = 47 kΩ. The analog output of MQ–135 gas sensor is connected to Analog pin 3 of Arduino UNO board. VRL and Ro can be obtained for MQ–135 gassensor with Arduino UNO board using the following small code:

```
for(inttest_cycle = 1; test_cycle<= 500; test_cycle++)
{
analog_value = analog_value + analogRead(A0);
}
analog_value = analog_value/500.0;
VRL = analog_value*(5.0/1023.0);
```

From the code, we obtained the value of Ro = 25 KΩ, But from the relation Rs/Ro=3.6. Hence, Ro can be easily calculated, utilizing MQ -135 sensor for the measurement of gases in the environment. The values of NH_3, CO_2 and CO gases lines in the graph are nonlinear, so the relation between Rs/Ro and concentration of gas in ppm is actually logarithmic.

$\log y = m*\log(x)+b$, where y=Rs/Ro, x=ppm, m=slope of the line, b=intersection point

Get the values of (x_1,y_1), (x_2,y_2) from the graph then:

$$m=[\log(y_2)-\log(y_1)]/[\log(x_2)-\log(x_1)]$$

$$b=\log(y)-m*\log(x)$$

$$\text{Concentration of gas (ppm)}=10\left\{\frac{\left[\log\left(\frac{Rs}{Ro}\right)-b\right]}{m}\right\}$$

From the above calculations using datasheets of MQ–135 gas sensor, we obtained the slope and intercept values for NH_3, CO_2 and CO gases from the following table.

Tab. 1: Slope and Intercept Values of NH_3, CO_2 and CO Gases

Gases	Slope (m)	Intercept (b)
NH_3	-0.263	0.42
CO_2	-0.152	0.71
CO	-0.1787	1.415

2.6 HC-05 Bluetooth Module

HC-05 Bluetooth module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Figs. 8 and 9 indicates circuit diagram of HC-05 Bluetooth Module with Arduino UNO board. Its communication is via serial communication which makes a simple way to interface with controller or PC. HC-05 Bluetooth module offers switching mode between master and slave mode which means it able to use neither receiving nor transmitting data. HC-05 Bluetooth module creates a wireless interface between Arduino UNO board and smart phone, the HC-05 module interfaced with Arduino using software serial command, HC- 05 module is connected to digital pins 3 and 4 of Arduino UNO board. Tab. 2 illustrates the pin connections with Arduino UNO microcontroller board and sensors.

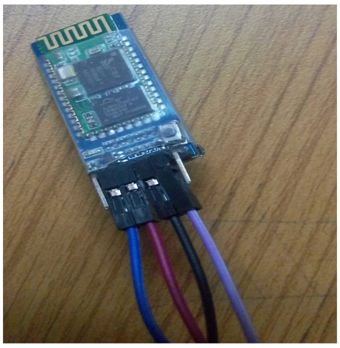

Fig. 8: HC-05 Bluetooth Module

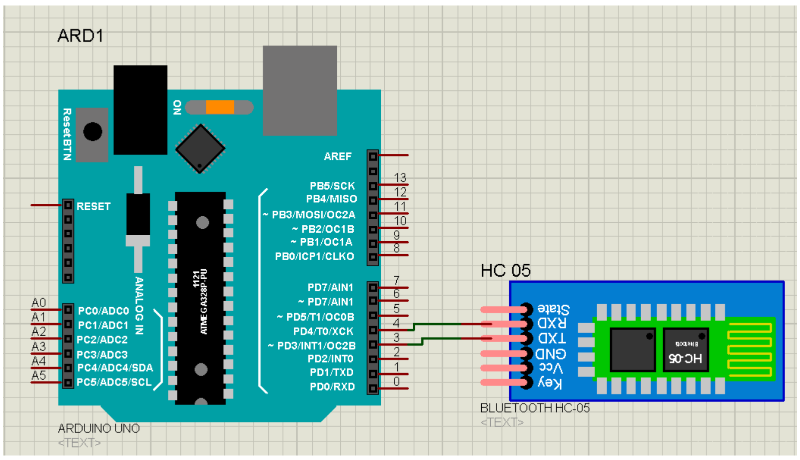

Fig. 9: Circuit Diagram of HC-05 Bluetooth Module with Arduino UNO Board

Tab. 2: Pin Connections with Arduino UNO Microcontroller Board to Sensors

S. No	Pin I/O	Jenis Pin	Mode Pin	Devices
1	0	Digital	Input	Receives data from laptop through USB cable (serial communication).
2	1	Digital	Output	Sends data to laptop through USB cable (serial communication).
3	3	Digital	Input	Receives data from mobile through HC–05 bluetooth module (serial communication).
4	4	Digital	Output	Sends data to mobile through HC–05 bluetooth module (Serial Communication).
5	2	Digital	Input	DHT–11 sensor module.
6	A3	Analog	Input	MQ–135 gas sensor.

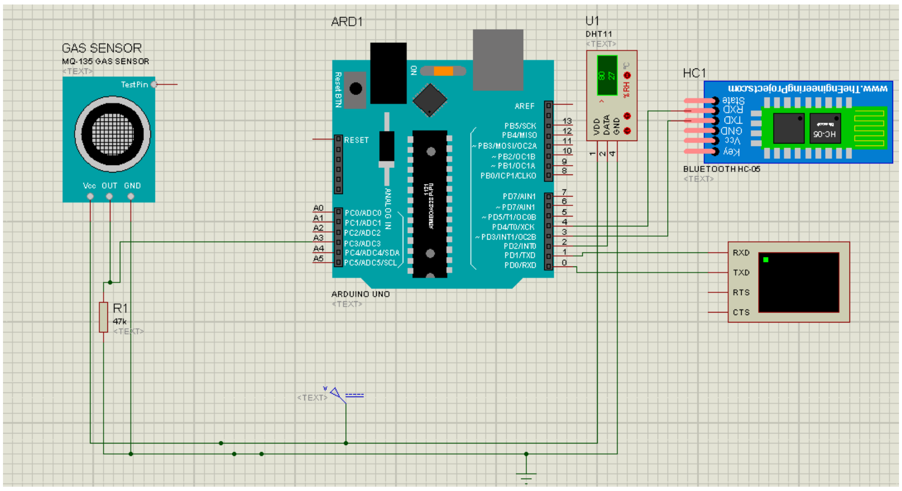

Fig. 10: Complete Circuit Diagram of Air Quality Monitoring System

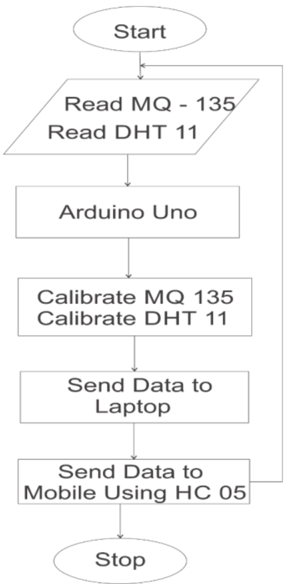

Fig. 11: Flow Chart for Obtaining Data from the Sensors Provided to Arduino UNO Board

The flow chart of the system in Fig. 11 illustrates data from the sensors provided to Arduino UNO board. Process the data of MQ135 using the data sheets with different slopes, we acquire the data of NH3, CO2, CO then calibrate it. This data now connected to laptop using PLX-DAQ the data possessed into an excel sheet, which can be further used. PLX-DAQ is a Parallax microcontroller data acquisition add-on tool for Microsoft Excel. Arduino UNO connected to the sensors and the serial port of a PC can now send data directly into Excel.

3. RESULTS AND DISCUSSIONS:

In this part, the real device implementation will be accessible. NH_3, CO_2, CO, humidity and temperature experimental set up will be discussed, as well as their results and discussions. The experimental set up for air quality monitoring is illustrated in the Fig. 12 (a) (b) and (c).

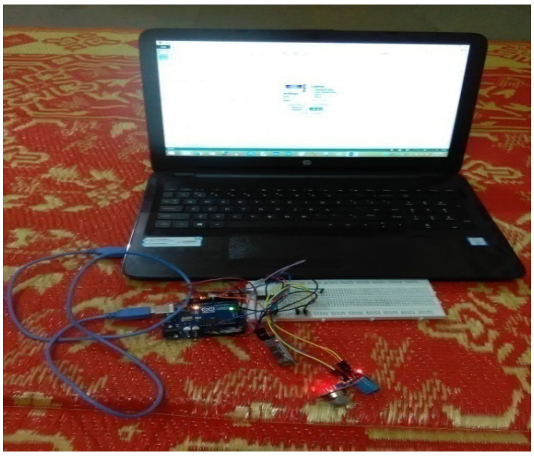

Fig. 12(a): The Experimental Set up for Air Quality Monitoring (Indoor)

Fig. 12(b): The Experimental Set up for Air Quality Monitoring (Outdoor)

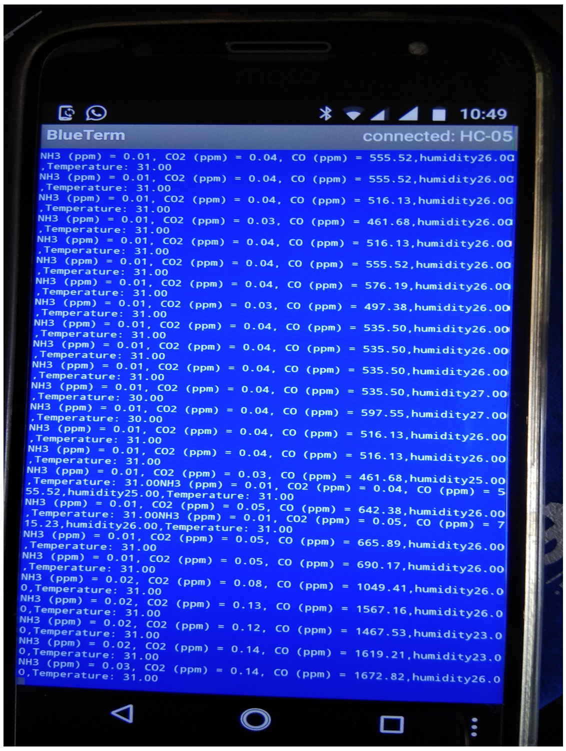

Fig. 12(c): The Experimental Set up for Air Quality Monitoringby Smartphone

Before testing for overall system, we performed several experiments for calibration of sensors. Experiments are performed by this system in outdoor and indoor locations. Fig. 13(a) indicates concentration of NH_3, CO_2, CO gases in ppm Vs time in minutes for outdoor location and Fig. 13(b) indicates temperature, relative humidity Vs time in minutes for outdoor location. It can be observed that from the Fig. 13(a), the concentration of CO and CO_2 are more while the concentration of NH_3 is less. It can be observed that from the Fig. 13(b), the temperature is more as the readings were taken at afternoon and simultaneously the relative humidity is less due to outdoor location in Hyderabad

Fig. 14(a) indicates concentration of NH_3, CO_2, CO gases in ppm Vs time in minutes for indoor location and Fig. 14(b) indicates temperature, relative humidity Vs time in minutes for indoor location. It can be observed that from the Fig. 14(a), the concentration of CO gas is more while the concentration of CO_2, NH_3 is almost negligible. It can be observed that from the Fig. 14(b), the temperature is more as the readings were taken at afternoon and simultaneously we observe the relative humidity in the indoor location. From Fig. 13(b) and Fig. 14(b) we infer that relative humidity is more in the indoor location.

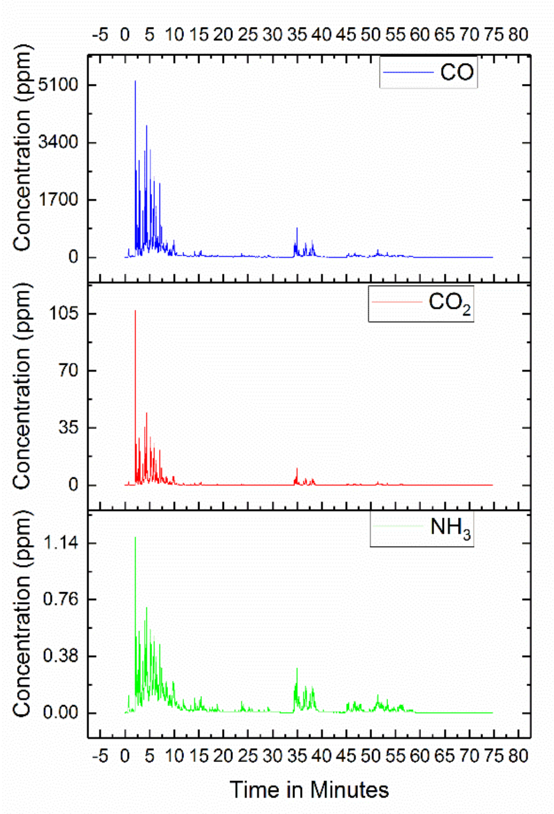

Fig. 13(a): Concentration of NH_3, CO_2, CO Gases in PPM Vs Time in Minutes for Outdoor Location

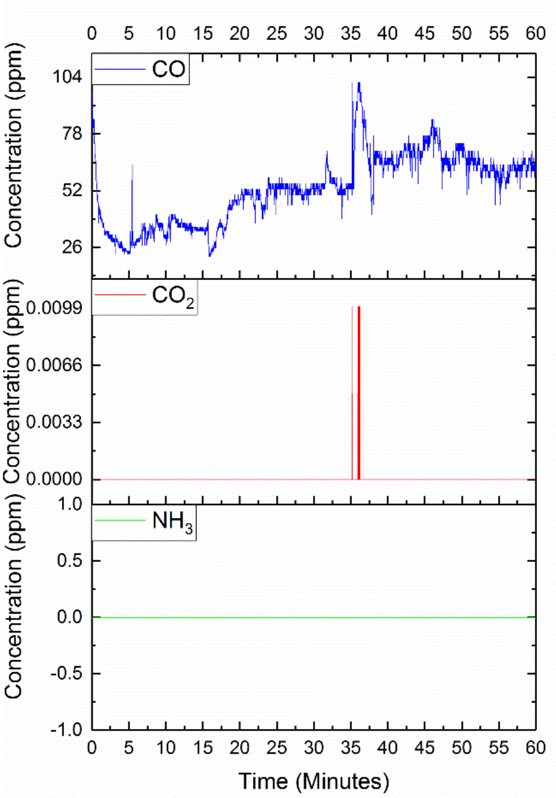

Fig. 14(a): Concentration of NH_3, CO_2, CO Gases in PPM Vs Time in Minutes for Indoor Location

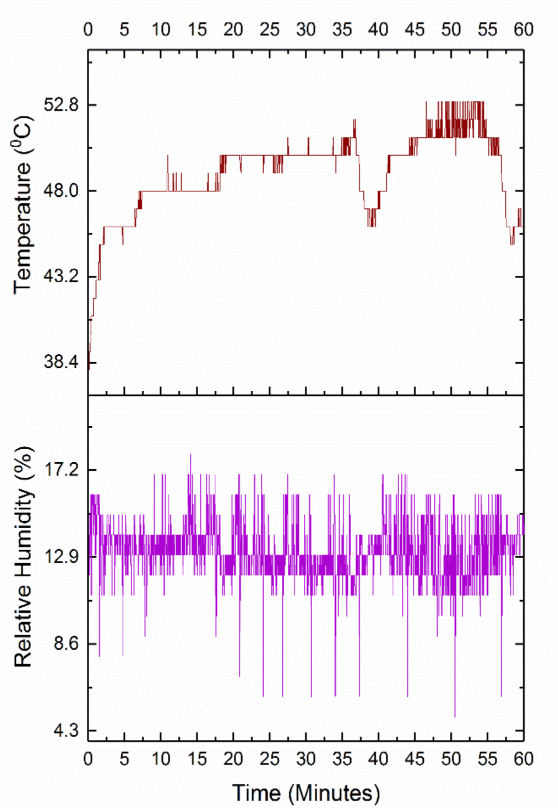

Fig. 13(b): Temperature, Relative Humidity Vs Time in Minutes for Outdoor Location

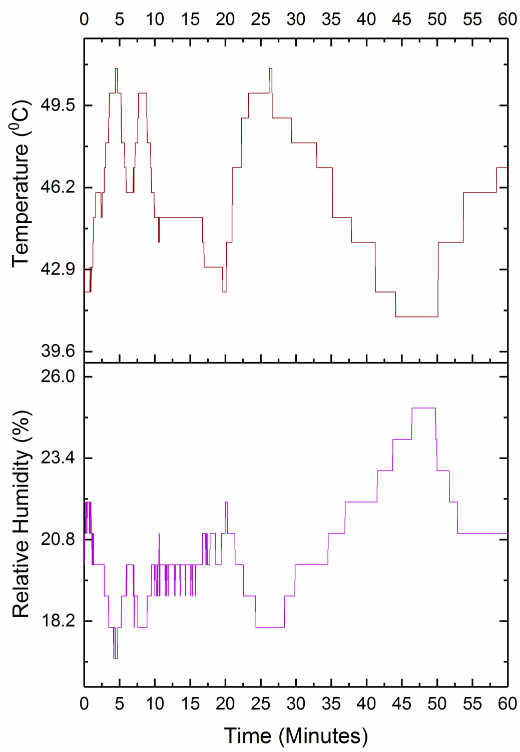

Fig. 14(b): Temperature, Relative Humidity Vs Time in Minutes for Indoor Location

4 CONCLUSIONS

In this present paper, an outdoor and indoor low cost air quality monitoring sensor system is successfully developed and designed. This system utilizes Arduino UNO board as the microcontroller for obtaining the concentration of three gases (CO, CO_2 and NH_3), relative humidity and temperature. This system is portable, convenient and cost effective to monitor the gases anywhere. Therefore, this system is particularly significant and contribute for the measurement of concentrations of CO, CO_2 and NH_3 gases in ppm with respect to time and they are capable for the measurement of temperature, relative humidity with respect to time.

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