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Design and Fabrication of a Teleoperated Explorer Mobile Robot

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***Abstract*—The exploration of unknown terrain can be dangerous without having proper data about the environment. In this paper, a mobile robot is demonstrated which can communicate wirelessly and also capable of providing some important parameters of the environment such as relative humidity, temperature, amount of methane, Carbon-di-Oxide and Carbon mono-oxide. The robot is designed as a small cart to achieve flexibility in motion and equipped with 3G module to communicate and collect data wirelessly. Later, the data collected from the robot are evaluated and analyzed to have a clear idea of the environment, the robot dealing with.**

Keywords—Mobile robot; Explorer robot; Gas sensor; Humidity sensor; Temperature sensor; Remote control.

I. Introduction

Generally, Human being are curious in nature. Exploring unknown places is not a new kind of adventure that many people opt for. But in many cases not knowing what is awaiting there oftentimes leads people to danger, even death [1]. So, to gather the information about the environment before arriving there in person, robots can be sent those places which can give us the exact information about the targeted location. For these reasons, mobile robots are employed. That way any surprises can be avoided along with the danger they are related to. Mobile Robot is a special purpose robot which can be either be autonomous or human operated, capable of providing the information required to know about an unexplored or a dangerous place via wireless communication. As the robot can operate independently, the controller need not be physically present on the mobile platform, it can be very useful in some other cases too. For example, in some cases, robots used in manufacturing plants, where the environment is highly controlled, an autonomous robot cannot always be programmed to execute predefined actions because one does not know in advance what will be the universe of required sensory motor transformations required by the various situations that the robot might encounter. And the environmental conditions may change time to time without giving prior signals. Also, nowadays, there are so many scientific expedition going on, numerous number of mine sectors, mineral mines such as coal mines, copper mines, etc. Everyday a lot of workers work in these mines in order to collect valuable mineral such as iron, coal, copper, petroleum, etc. These mines are not always of user friendly environment. For example it can be mentioned that the temperature of these mines may be of such, which would be greatly harmful for the workers. Besides this, the percentage of humidity may not provide an environment which would not be comfortable for the people working there. In addition, it is very obvious that, there would be presence of several types of toxic gases such as methane (CH_4) [2], Carbon-di-Oxide (CO_2) [3] carbon monoxide (CO) [4], etc. In this study, the main objective is to analyze the performance of a teleoperated explorer mobile robot and also evaluate the data collected from the environment using the robot in nature. To do so, in this project, LM-35 is used for sensing and measuring temperature, HG-20j for measuring relative humidity, MQ-138 for sensing the gases, IR sensor to avoid obstacles and nRF24L01 for high speed wireless 3G communication.

II. Literature Survey

The history of making special purpose robots is almost century old. Many researchers have explained the necessity of obstacle avoiding robot and also described the way to make them [5]. Also there are many solutions to plan the path of the robot to cover the area in shortest possible time [6] [7]. During World War II, the endeavor to make first mobile robots advances as a result of technological and scientific breakthrough on a number of relatively new research fields like computer science and cybernetics [8]. The main purpose of those robots to carry bomb to detonate in distant locations. The engineers made those robots equipped with RADAR control and smart guidance system so that they detonate at their targeted locations to ensure maximum damage to the enemy bases. Some of those flying machines had autopilot and automatic detonation systems. Even though they were mostly the predecessors of modern cruise missiles, their usefulness opened the new window for remotely operated robots. Another example is Elmer and Elsie [9]. These autonomous robots could explore their environment. Elmer and Elsie were each equipped with a light sensor. If they found a light source they would move towards it, avoiding or moving obstacles on their way. These robots demonstrated that complex behavior could arise from a simple design. Elmer and Elsie only had the

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equivalent of two nerve cells. But the history of mobile robots can never be written without mentioning the contributions made by NASA. In 1976, NASA reportedly sent two unmanned spacecrafts to Mars [10]. Later in 1996 to 1997 NASA sent the Mars Pathfinder [11] with its rover Sojourner to Mars. The rover explored the surface as, commanded from earth. Sojourner was equipped with a hazard avoidance system. This enabled Sojourner to autonomously find its way through unknown terrain.Another use of the mobile robot is simultaneous map building [12] and localization of different places which can be achieved either by robust regression model [13] or using sensor network [14].

III. Methodology

The development of mobile robot requires proper planning and testing which can be describes as shown in Figure 1. The development stages can be divided into two categories: Hardware and Software development for the mobile robot.

Hardware development can also be classified into Mechanical and Electronics Components. In case of mechanical body development, the stages are:

- Design Model
- Prototype and
- Project Model development.

Electrical and electronics components are finalized through following steps:

- Circuit diagram
- Circuit Simulation and
- Circuit making

Apart from building and integrating mechanical and electrical components, a software is required to control the mobile robot. The whole process is shown in Figure 1.

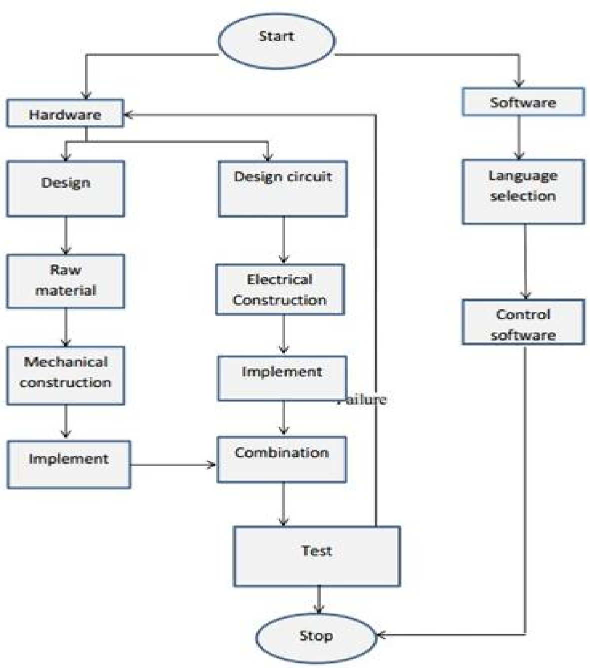

Figure 1: Development stages of a Mobile Robot

IV. Advantages of Implemented mobile robot over previous works

The main advantages of the mobile robots can be as follows-

- The overall cost of the system is minimum (less than $100)
- The sensors used in the study are capable of providing wide range of data in response to the slightest atmospheric change.
- The implemented gas sensor detects LPG, along with CO and CO_2 and can also be calibrated to detect many other gases if necessary.
- The robot is autonomous both in mobility and data transmission over long distance which makes it convenient for places where human health is an issue.

V. System Design

The mobile robot is designed and built as simple as possible without compromising its performance over long distance data transmission of the working environment so that the operators can have a clear idea about the working hazards which they might be subjected to otherwise taking precautions. The overall design of the mobile robot module is shown in Figure 2.

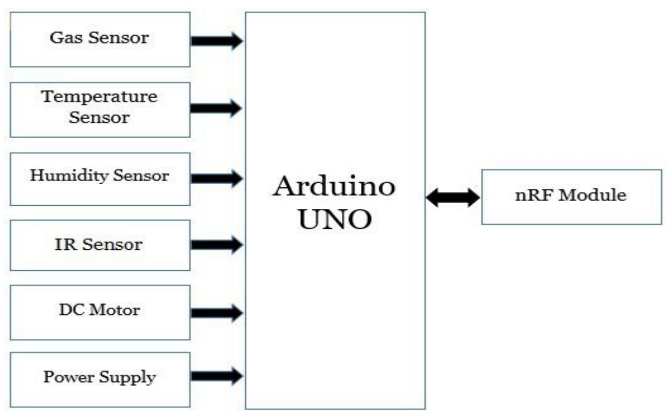

Figure 2: Block diagram of the Robot Module (TX) with data flow direction

During operation the sensor data is continuously collected by the robot module and send to the server by using nRF module. The receiving end of the Mobile robot data is shown in Figure 3 where the RX module receives the data send from the robot and later shown in monitor in real time.

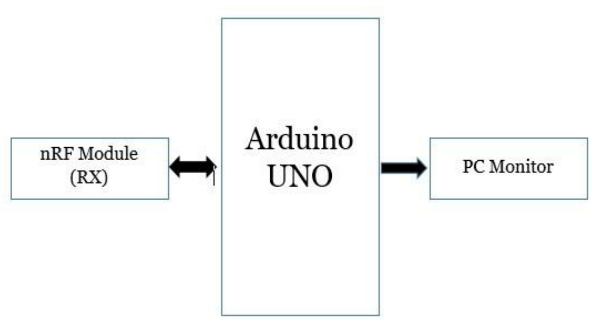

Figure 3: Block diagram of the Operator Module (RX) with data flow direction

A. Mechanical Construction

The base structure is made of aluminum. The box shaped main body part is shown in Figure 4, for the placement and supplement of the overall circuit and also it is made of Aluminum, because of its light weight and low density and for its ability to resist corrosion due to the phenomenon of passivation [15]. A free rotating cluster ball was attached at the front side of the structure in order to make the robot to move freely at all directions. Two DC- motor (geared motor) are located at rear side to serve as the driver wheel. A driver circuit was made for driving the motors. The dimension of the robot is 14 inch length and 8 inch wide.

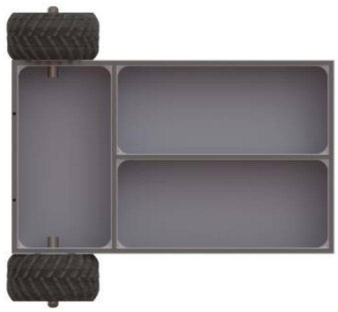

Figure 4: 3D Model of the Main Body of Robot

B. Electronics Components

The electronic circuit is consists of the components listed below:

a. Arduino-Uno
b. Temperature sensor (LM-35)[16]
c. Gas sensor (MQ-138)[17]
d. Humidity Sensor (HG-20j)
e. nRF Module (nRF24L01)[18]
f. DC-motor (Gear motor)
g. IR Sensor

C. Circuit Diagram

The circuit design of the mobile robot with data transmitter is shown in Figure 5.

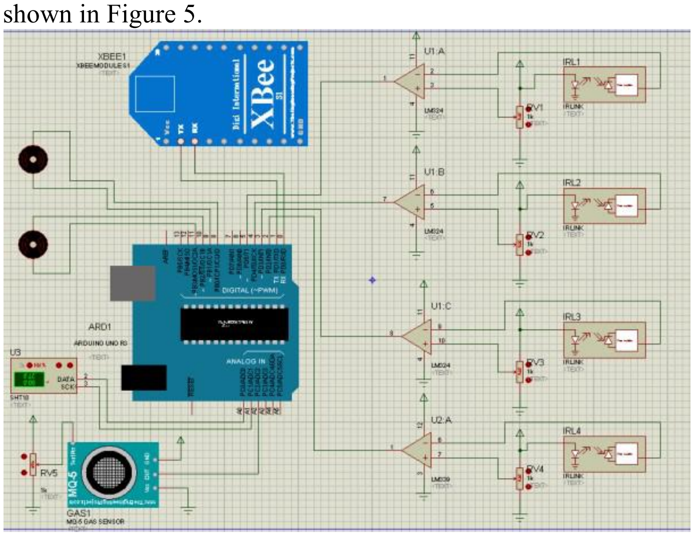

Figure 5: Circuit Diagram of the mobile robot TX module

The primary design and simulation was performed by using Proteus©. As there is no direct way to simulate the presence of gas, the simulation was conducted by using pseudo binary input to the Arduino. Also data transmission was conducted by Xbee module as there is no nRF module in Proteus. So the real circuit diagram is somewhat modified during implementation of the project. After successful design and simulation the circuit is built in breadboard for physical assessment. After successful implementation of the circuit it has been installed to the robot for the final checking. The results will be discussed in later chapters of the paper.

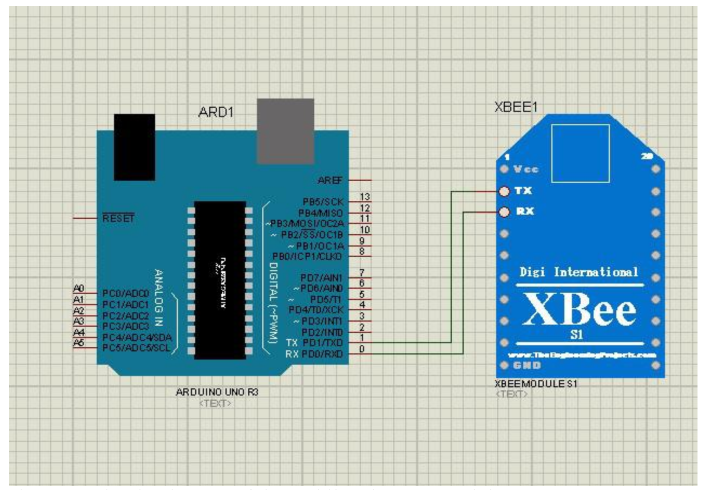

Figure 6: Circuit Diagram of the mobile robot RX module

The receiving end of the circuit designed with another Xbee module connected with RX pin of Arduino board, which is shown in Figure 6.

The data received from the robot module are send to the RX module which is interfaced with Computer and eventually displayed in the PC Monitor connected with the Arduino in Real-Time.

D. Gas Detection Mechanisms

Gas detectors [19] detects and measure the concentration of combustible and toxic gases presents in the air. Most toxic gas detectors are broadly classified into Electrochemical Gas sensor (carbon monoxide, chlorine and nitrogen oxides) and Metal-Oxide semiconductors (MOS) (commonly carbon monoxide. Similarly, Combustible Gas Sensors can be classified into Catalytic sensor and Infrared sensors based on the method employed to detect hydrocarbon gases [20].

VI. FABRICATED MOBILE ROBOT

There are two operating circuits used in this project. The c client circuit is one of them, which is mounted on the robot. It is the most important and also is more complicated than the other circuit (server circuit). It contains several parts, such as: An Arduino-Uno, IR sensors (transmitter and receiver), variable resistor, voltage regulator, one MOSFET two six volt battery (connected in series), several resistor (1KΩ, 20KΩ, 320Ω, etc.), nRF, MQ-138, IR sensor.

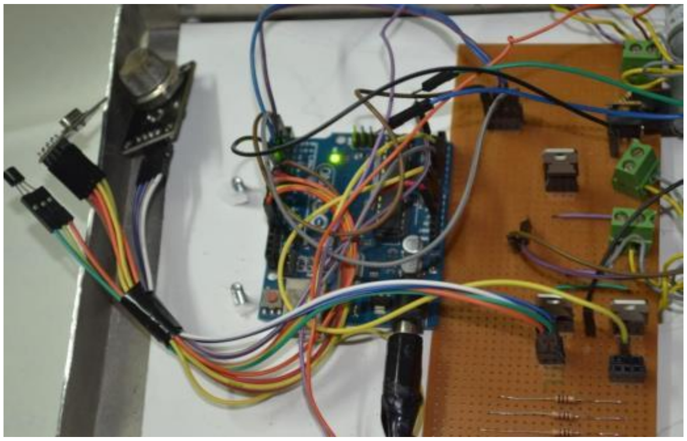

Figure 7: Circuit of the mobile robot TX module (Client Circuit)

The other circuit is connected to the LCD display (Laptop screen). Its function is to receive data, transmitted by the client circuit. It contains:

- An Arduino-Uno
- nRF

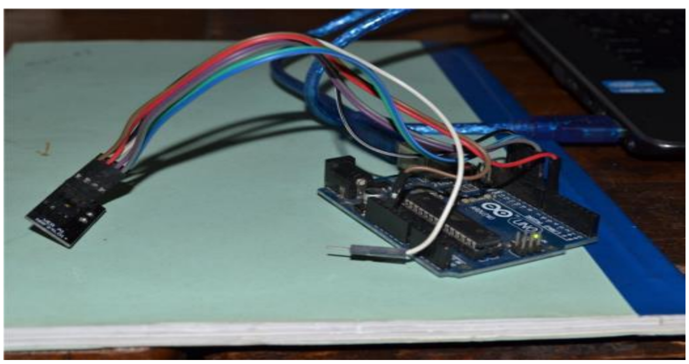

Figure 8: Circuit of the mobile robot RX module (Server circuit)

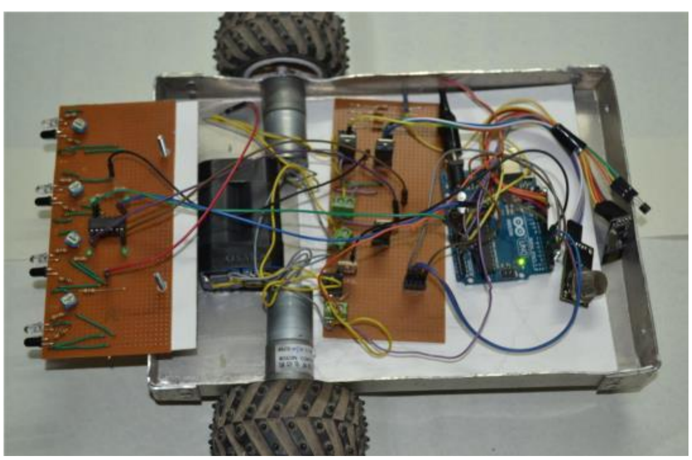

Figure 9: Implemented Mobile robot equipped with TX module

A. *Software Used*

There are four softwares used to implement the project which are:

a) *Arduino:* Both of the RX and TX module of the Robot is built and operated using Arduino UNO Board as it is both cheap and powerful for small scale robotic applications, which is very cheap from its counterparts too [21].

b) *Proteus:* The design and partial simulation of the project is done in Proteus which is very popular as well as very easy to use [22].

c) *Cool Term:* Cool Term is a software that can collect values from different sensors and preserve them in a text file.

d) *MATLAB:* MATLAB is a multipurpose software which ranges simple mathematical calculation to complex simulation model. In this project, the data which has been received from the module are plotted using MATLAB [23].

VII. EXPERIMENTAL DATA ANALYSIS

The aim of this project was to construct such a robot which can explore a remote area, say, for example, a coal mine or a diamond mine and help us to know about the workplace environment of the area which is under consideration by transmitting several weather data such as temperature and detection of toxic gas (here, carbon related gas). As it was not possible to make the experiment in any mine area, here, the experiment was conducted in room conditions and also the environment was created artificially by supplying different gases and the data was recorded accordingly. The collected data from the experiment are presented here.

In Figure-10 the change in relative humidity with respect to time is presented.

A.*)Relative Humidity*: Relative humidity is defined as the ratio of vapor pressure in the air with respect to the saturation vapor pressure.

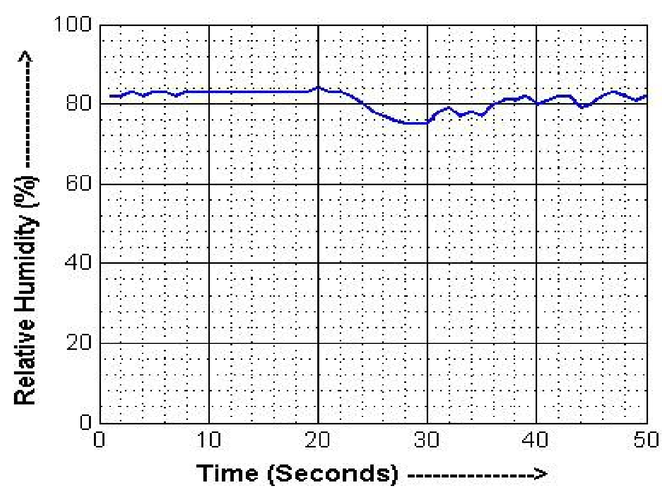

Figure 10: Variation of Relative Humidity of the environment over Time

During the experiment the relative humidity of the environment was fairly constant which is approximately 80%.

B. Temperature

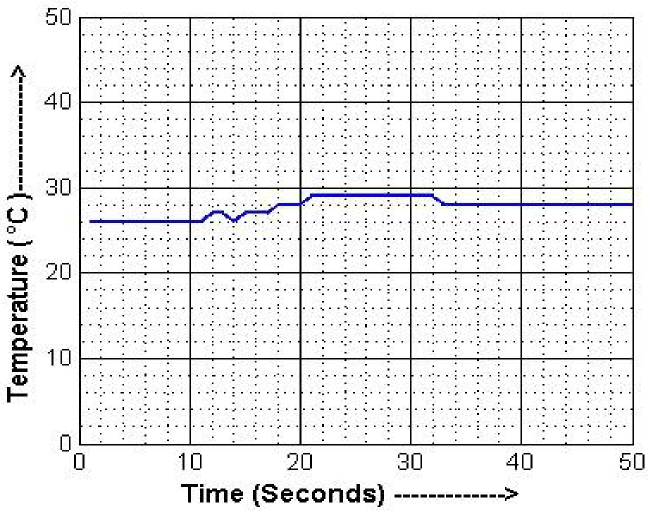

Figure 11: Variation of Temperature with respect to Time

In Figure-11 the change in temperature was minimal as we can see from the graph here and the room temperature was on average 28°C.

C. Methane (CH_4)

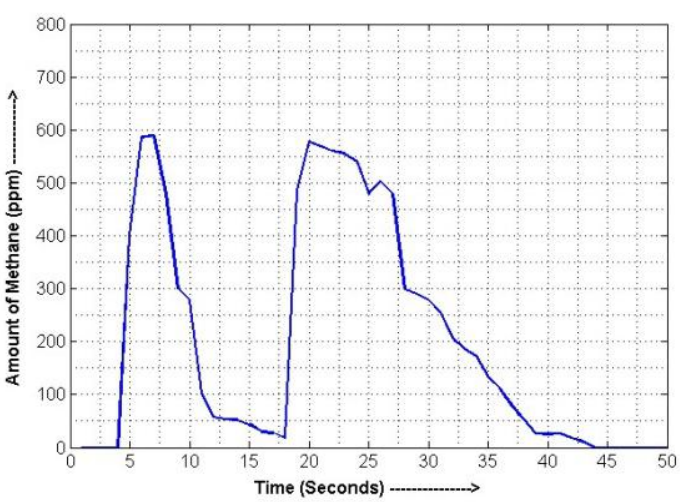

Figure 12: Variation of amount of CH_4 over Time

From the mobile robot, the amount of methane gas (in ppm) was recorded and presented in Figure-12. During the experiment the amount of CH_4 varied over the range of 0 ppm600 ppm. The sudden upraise in amount of methane occurred exactly the moment we released the gas and also the amount density of the gas reduced over time.

D. Carbon-di-oxide (CO_2)

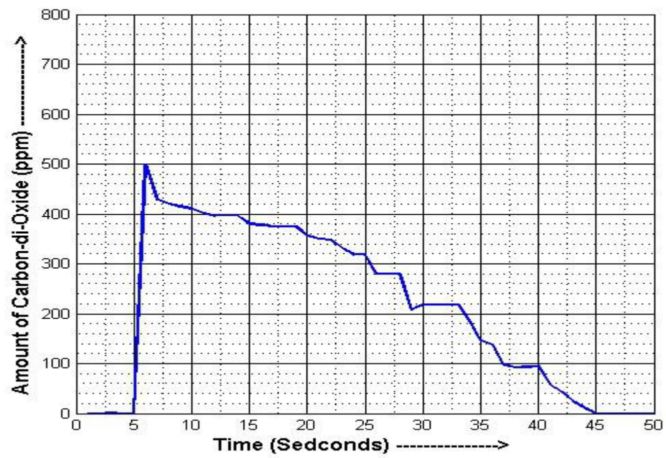

Figure 13: variation of amount of CO_2 over Time

Figure-13 shows the presence of CO_2 (in ppm) and recorded its variation over time. During the experiment the amount of CO_2 varied over the range of 0 ppm-500 ppm.

E. Carbon Monoxide

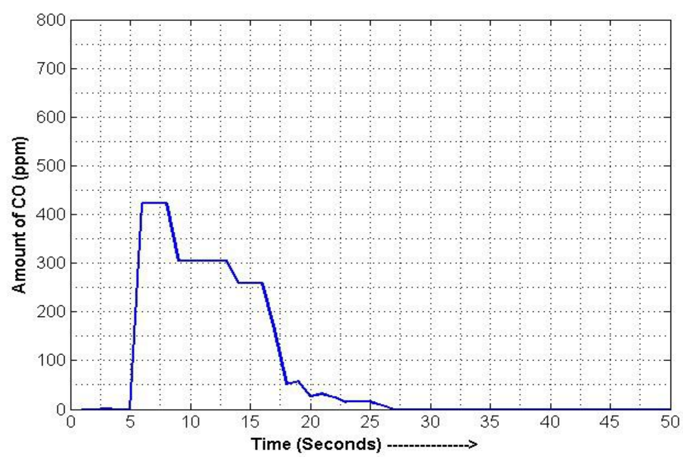

Figure 14: Variation of amount of CO over Time

Figure-14 shows the amount of CO (in ppm) and recorded its variation over time. During the experiment the amount of CO varied over the range of 0 ppm-450 ppm.

VIII. CONCLUSION

Engineers working on developing mobile robots and utilizing their ability to work independently with greater flexibility in different circumstances. This project was also something new that to use the robot in order to explore an unknown environment and collect several weather data. Further it might also be used as a land-mine detector robot.

Despite all the efforts to make the project as perfect, there were some limitations, which are

- The sensors used to build the robot were cheap and their sensibility was not up to the par, so the data
- collected was varied to a certain degree from its actual value, which was though expected.
- And Also the IR sensors are not the best choice for the obstacle avoidance application, but its use reduced our cost of development.
- The robot was tested in room conditions, so the actual outdoor performance is yet to be unveiled.
- Even the data are quite accurate when the concentration of gases are high in lower range it could not sense the presence of the gases, though it can be avoided by using better sensors and proper calibration.

IX. Reference

[1] "Toxic Vapors Suspected In Deaths Of Three Colorado Oil And Gas Workers – The Denver Post". *Denverpost.com*. N.p., 2015. Web. 1 Dec. 2016.

[2] "Is Methane Gas Harmful To Humans?" *Reference*. N.p., 2015. Web. 2 Dec. 2016.

[3] "CO_2 Science". *Co2science.org*. N.p., 2015. Web. 13 Dec. 2016.

[4] "How Carbon Monoxide Affects Your Health". *Aboutcarbonmonoxide.com*. N.p., 2015. Web. 1 Dec. 2016.

[5] O. Khatib, "Real-time obstacle avoidance for manipulators and mobile robots", *IJRR*, vol. 5, no. 1, pp. 90-98, 1986.

[6] I. Nikolos, K. Valavanis, N. Tsourveloudis, A. Kostaras, "Evolutionary algorithm based offline/online path planner for navigation", *IEEE SMC*, vol. 33, no. 6, pp. 898-912, Dec. 2003.

[7] C. Connolly, J. Burns, R. Weiss, "Path planning using laplace's equation", *IEEE ICRA*, vol. 3, pp. 2102-2106, Mai 1990.

[8] "An Insight Into The History Of Military Robots". *Armyofrobots.com*. N.p., 2016. Web. 7 Dec. 2016.

[9] "Elmer And Elsie". *Findery*. N.p., 2016. Web. 7 Dec. 2016.

[10] "Viking 1 & 2". *Mars.nasa.gov*. N.p., 2016. Web. 7 Dec. 2016.

[11] "Mars Pathfinder". *Mars.nasa.gov*. N.p., 2016. Web. 7 Dec. 2016.

[12] G. Anousaki and K. Kyriakopoulos, "Simultaneous localization and map building for mobile robot navigation", *IEEE Robotics & Automation Magazine*, vol. 6, no. 3, pp. 42-53, 1999.

[13] X. Zhang, A. Rad and Y. Wong, "A Robust Regression Model for Simultaneous Localization and Mapping in Autonomous Mobile Robot", *Journal of Intelligent and Robotic Systems*, vol. 53, no. 2, pp. 183-202, 2008.

[14] T. Jin and H. Bashimoto, "Simultaneous Localization and Mobile Robot Navigation using a Sensor Network", *International Journal of Fuzzy Logic and Intelligent Systems*, vol. 6, no. 2, pp. 161-166, 2006.

[15] Extrusions, Capral. "Aluminium And Aluminium Alloys - Characteristic Advantages And Beneficial Properties Of Aluminium Extrusions By CapralAluminium". *AZoM.com*. N.p., 2014. Web. 2 Dec. 2016.

[16] "LM35 Datasheet(PDF) – National Semiconductor". *Alldatasheet.com*. N.p., 2010. Web. 5 Dec. 2016.

[17] "Sainsmart MQ138 Formaldehyde Aldehydes Gas Detection Sensor Module 3D Printing, Arduino, Robotics | Sainsmart". *Sainsmart.com*. N.p., 2015. Web. 2 Dec. 2016.

[18] Systems, eZ. "Nrf24l01 / 2.4Ghz RF / Products / Home - Ultra Low Power Wireless Solutions From NORDICSEMICONDUCTOR". *Nordicsemi.com*. N.p., 2014. Web. 3 Dec. 2016.

[19] "Gas detection sensor", *Metal Finishing*, vol. 93, no. 2, p. 100, 1995

[20] "How Gas Detectors Work", *Thomasnet.com*, 2017. [Online]. Available: http://www.thomasnet.com/articles/instruments-controls/How-Gas-Detectors-Work. [Accessed: 18- Jan- 2017].

[21] "Arduino - Home". *Arduino.cc*. N.p., 2009. Web. 1 Dec. 2016.

[22] "Proteus PCB Design & Simulation Software - Labcenter Electronics". *Labcenter.com*. N.p., 2010. Web. 4 Dec. 2016.

[23] "MATLAB - Mathworks - MATLAB & Simulink". *Mathworks.com*. N.p., 2008. Web. 3 Dec. 2016.