Fully Autonomous Flammable Gases (Methane Gas) Sensing and Surveillance Robot

Wajih Ahmed Memon, and Muhammad Bilal

***Abstract*—**In the light of *safety* and *environmental* protection there has been number of things done in the world but this paper is particularly focusing on the industrial health and safety. This paper includes building of an *autonomous* gas detecting robot that is made capable of patrolling around the industrial field while detecting flammable and toxic gases like: Methane and H2S traces in the environment in *PPMs* and *wirelessly* transmitting those *concentration* values to the receiver station. Several different gas leakage detection devices and systems are made and implemented but those are all stationary (non-mobile) and fitted at a point but this is made keeping in view the modernization and innovation of the industrial world. The results in this paper have been developed on various concentration values of Methane gas though simulation can be made for other gases too but here we will focus on detection of Methane only.

***Keywords*—**Concentration, Flammable gases, PPMs, Safety

I. Introduction & Working Methodology

NATURAL gas is an important source of energy in the world [1]. If we look the composition of natural gas, it consists of about *94% methane* which gives high energy on combustion. Being the cheap source of energy, the industrial and power sectors of the world majorly depends on natural gas usage [2]. Number of textiles, fertilizer and processing industries are running on Natural Gas. Most of the Independent Power Plants (IPP's) are working on Natural gas and significance of *Compressed Natural Gas (CNG)* in transport clearly implies that Natural Gases is a great blessing for third world countries in accomplishing their energy needs[3].

However it is a matter of fact that natural gas is highly flammable, odorless and colorless gas and can lead to great disaster even if its concentration in atmosphere is only *300ppm*. With naked eyes and conventional instruments its leakage is undetectable. In industries and power plants there are number of positions and locations where leakage is expected [4], [5], and history evident the number of such disasters occurred due to improper control and monitoring of such leakages [6].

This paper is written for the industrial application of such a type of robotic system that is new, economical & environmentally sustainable [7], that has never been made or implemented in the industries [8]. There are number of static nonmoving sensors and devices present in the industries that are having capability of leakage of any dangerous gases but there are no such mobile patrolling detection system, that is made capable for patrolling around the field and electronically detecting the flammable gases with the help of *stannic oxide(SnO_2)*sensor the concentration of leaking gasses that are prone to explosion and environmental deterioration particularly methane gas, it also includes wireless 2 axis tracking camera for the detection of the point of leakage or excessive concentration obtained and ultrasonic range sensors are used for the obstacle detection in case of any. The gas sensor, camera, robot motors, and xbee transmission modules are all [9], preprogrammed using a popular microcontroller arduino that is programmed using external computers with arduino programming. This microcontroller works on 5V PWM signals with 3906Hz frequency.

This robot uses two 12V DC motors connect on each wheel, the construction of the robot is such that it steers on its body center with 360 degrees rotation on its central axis that are programmed, the gas sensor as shown in (Fig.8) gives analog real time output [10], that is wirelessly transmitted by using transmitter *xbee* 60mW [11],module having the range of around 1.5km to the receiver xbee module that is connected on the arduino microcontroller input pins that will process the input signals that are of gas sensors and will give the output of it in *PPMs* that can be processed further with *MatLab* or *Lab VIEW* algorithm to obtain graphical results as shown in (Fig.10) and practical results are shown in (Fig.12,13,14 & 15) also the other way of process is by using seven segment LED to be mounted on the robot or can be used on the receiver station and arduino program is to be used to process the signals and the concentration found in PPM is shown in the numerical form on seven segment LED *1=100PPM* as shown in (Fig.9) result is shown in (Fig.15), 5V piezo Buzzer and Seven segments single digit LED that shows the concentration of leaking gas in proportion. The Displayed number shows the proportion of concentration of flammable gas in air which is programmed through Arduino. The wireless camera is mounted on the two 180^o *servo motors* that are also programmed to move the camera in 2 axis (vertical and horizontal) to have the view of terrain, signals are transmitted to the receiver of the camera and USB video device is used to have the wireless transmission of camera on screen. Ultrasonic

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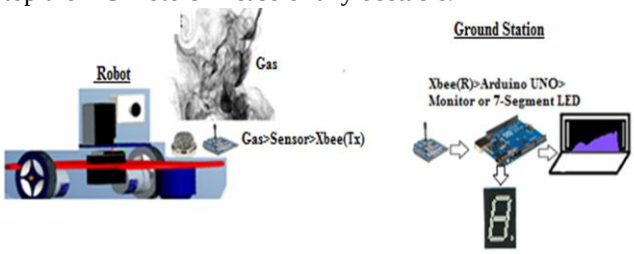
range sensors are used that are embedded with the DC motors to stop the DC motors in case of any obstacle.



II. Mechanical Design & Prototype Model

In order to have perfection in functioning and application of robot, it is necessary to take help from any CAD software like: Pro-Engineer. Design of Pro-Engineer *cad model* and the *prototype model* of our robot is shown:

Fig. 1 Body design

Fig. 2 Pro-E Design

Fig. 3 Pro-E Design

Fig. 4 Prototype Model

Body Material: *Acrylic* (Glass fiber) 3mm thick sheet.

Body Dimensions: 10''X 8'' plate having thickness of 3mm.

Front Steering: Using *Ball Caster ¾"* Ball.

Fig. 4 Ball caster (Front Steering)

Rear Wheels: Axle-less wheels each mounted with separate DC Motors 2 ½'' diameters each.

TABLE I
Specifications Of Construction Components

S.no	Components	Quantity	Electrical specs	Mechanical Specs
01	DC geared motor	02	12V,300mA (Free) 5A(Stall)	Torque 14 Kg-cm RPM-200
02	Servo Motors	02	5-7v	Maximum Torque: 64 ounce-inch
03	Wire Less RC Camera	01	-View angle 62 degrees - illuminatio n: 1.5 Lux	500m(can be amplified with amplifiers)
04	Arduino micro-controller	02	5V-15V input 5V PWM output	N/A
05	Methane gas sensor	01	5000ppm to 20000ppm range	Stannic oxide (SnO_2)
06	H-Bridge IC	01	For the DC motor	N/A
07	Xbee wireless modules	02	60mW output (1500m) range	N/A
08	7- segment LED	01	2V	N/A
09	Motor battery	01	12V Ni-MH 4200Mah	N/A
10	Arduino battery	01	9V Ni-MH 1000Mah	N/A

III. Circuit & Schematic Diagrams

This IC based H-bridge is a bridge b/w microcontroller and DC motors to run the DC motors according to desired program uploaded in microcontroller.

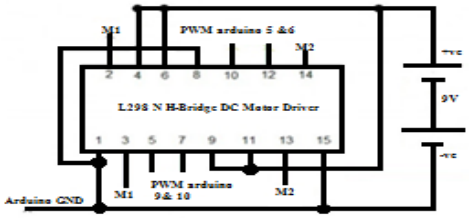


Fig. 5 Driving circuit for DC motors

This is the schematic of motor drives, including two DC motors for robot movement and two servo motors for camera 2 DoF (pitching and yawning) movement

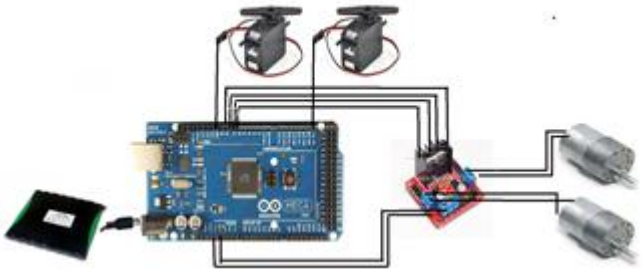


Fig.6 Schematic diagram for the DC & Servo motors

This is the internal circuit of gas sensor showing the SnO_2 element used to sense the gas.

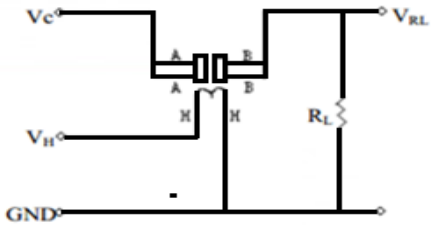


Fig.7 Gas Sensor Internal Circuit

This is the Xbee based wireless gas sensor signal transmission schematic diagram.

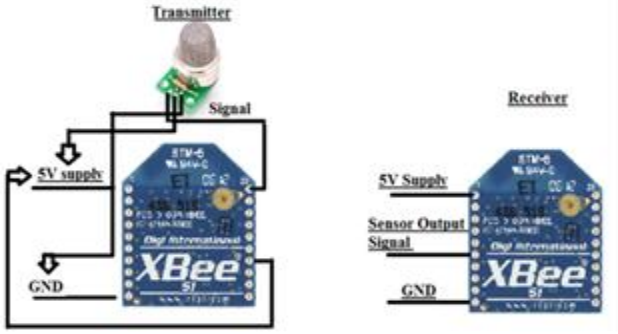


Fig. 8 Xbee Gas Sensor Wireless

This is the 7-Segment LED based Arduino Gas sensor circuit used to display the gas sensed in digits on LED (1=100PPM).Sensor signal input from the receiver xbee.

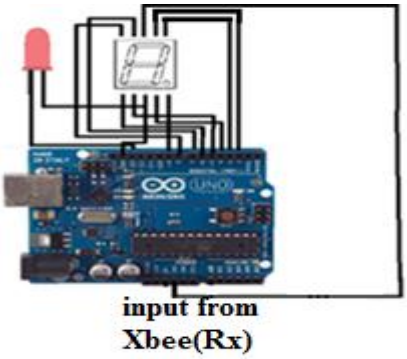


Fig. 9 7-Segment LED Arduino

This is the schematic diagram of gas sensor values that are received from xbee(Rx) are read by the arduino on the ground station and viewed real time data, on arduino serial monitor.

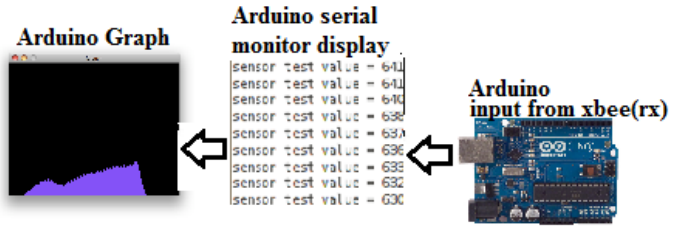


Fig. 10 Arduino Serial Monitor Display

This is the block diagram of xbee wireless gas sensing system that has output on arduino monitor or 7-segment LED .

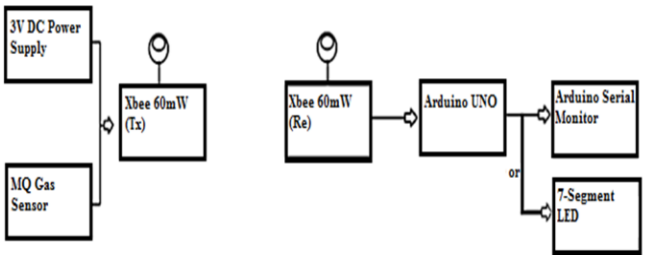


Fig. 11 Gas Sensor (Xbee wireless system output on arduino monitor or LED) Block Diagram

This is the block diagram of wireless (2.dof) camera used for the surveillance purpose in the field.

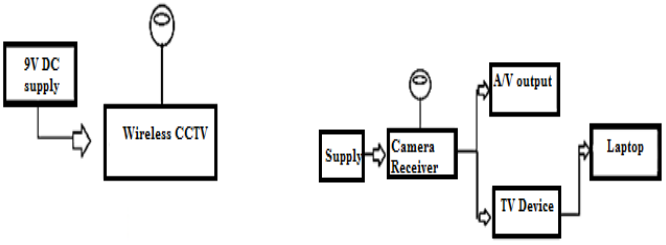


Fig. 11 Wireless Camera Transmission Block Diagram

IV. Results

A. Arduino Serial Monitor's Output:

This is the wireless output that is obtained by connecting gas sensor to xbee transmitter module on the robot and the signals obtained at the receiver module of xbee at the receiver

station (Fig.8), is further connected to input of arduino that has arduino gas sensor serial monitor display program that will process the wirelessly transmitted signals input to it from xbee(Rx) and gives following output.

```
sensor test value = 144
sensor test value = 144
sensor test value = 145
sensor test value = 145
sensor test value = 144
sensor test value = 144
sensor test value = 144
sensor test value = 144
sensor test value = 144
sensor test value = 143
sensor test value = 143
sensor test value = 143
sensor test value = 143
sensor test value = 143
```

Fig. 12 Arduino monitor result in PPMs when gas sensor is not exposed to methane gas

```
sensor test value = 634
sensor test value = 638
sensor test value = 639
sensor test value = 640
sensor test value = 641
sensor test value = 641
sensor test value = 640
sensor test value = 638
sensor test value = 637
sensor test value = 636
sensor test value = 633
sensor test value = 632
sensor test value = 630
sensor test value = 628
```

Fig. 13 Arduino monitor result in PPMs when gas sensor is exposed to methane gas

B. Graphical Output Of Gas Sensor In Millivolts

It shows the variation in output voltage graph of the gas sensor module whose signals are transmitted wirelessly to the ground station with the help of xbee module, in millivolts for the period of 30Secs, shows output when in uncontaminated air and contaminated air. This is also done by inputting the xbee(Rx) signals to the arduino the schematic is shown in (Fig.10).

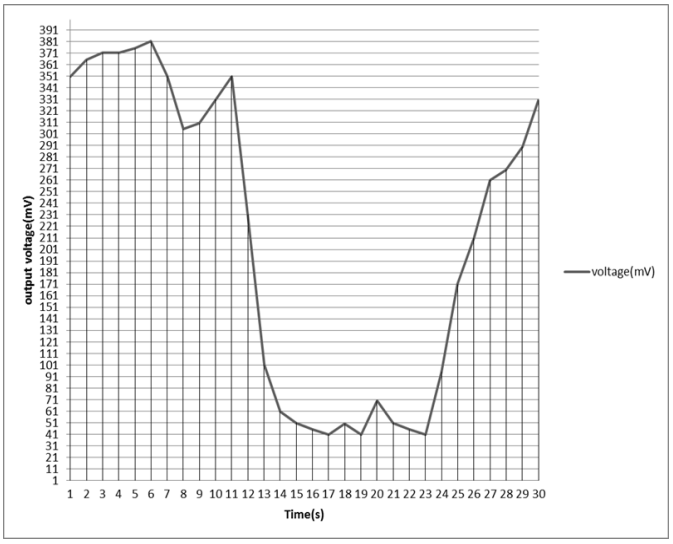


Fig. 14 Flammable Gas detection Graph

C. 7-Segment Led Output Result

Below shows the output of the gas sensor that is obtained by using the 7-segment LED display, the arduino is programmed and the concentration values of the gas sensed will be shown as under on the LED display the schematic is shown in (Fig.9). When it detects the concentration of flammable gas above 300 ppm, it will switch the buzzer and LED display will show a number in proportion to the concentration.

Led display =1 when concentration is < 400ppm
Led display =2 when concentration is < 500ppm
Led display =3 when concentration is < 600ppm
Led display =4 when concentration is < 700ppm
Led display =5 when concentration is < 800ppm
Led display =6 when concentration is < 900ppm

LED Display	Concentration (less than in ppm)	LED Display	Concentration (less than in ppm)
0	300	5	800
1	400	6	900
2	500	7	1000
3	600	8	1100
4	700	9	1200

Fig. 15 7-Segment LED display table

V. Conclusion

The prototype of the robot was made as shown in (Fig.4) and it was made to work in several contaminated environment and the real-time results were obtained wirelessly up till the range of 1000m on arduino microcontroller monitor shown in (Fig.12) and (Fig.13) and on 7-segment LED as shown in (Fig.15) according to the program in microcontroller. According to the above results it is concluded that this

intelligent sensing & surveillance robot can be implemented in several industries especially chemical and oil/gas industries giving the real-time values of the concentration of flammable gases to the ground station which can help in disaster prevention while increasing the level of monitoring and safety measures of the industry.

Scope for further modifications and changes for extensive applications is present. It can also be advanced by developing software so as to bring at par with this computer age.

Nomenclatures

A/V Audio & Video.
GND Electrical Ground connection.
H2S Hydrogen Sulfide.
LED Light Emitting Diode.
PPM Parts Per Million.
PWM Pulse Width Modulation.
Rx Receiver.
Tx Transmitter.

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