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ZigBee & Microcontroller Based Multi Sensors Artificial Intelligent Technique for Gas Identification.

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Abstract

ZigBee & microcontroller based gas sensing system is presented in this paper. The analysis presented here depends on thin film metal oxide gas sensors, TGS 822, TGS 813, TGS 2600, TGS 3870 and TGS 4160. The differences in the steady state performance among their sensors are used for improving their selectivity and sensitivity, while the combination of gas sensors permits success in gas classification problems. In the approach the gas sensors are embedded into a chamber with a heating system. Different types of gases are used, such as, Methane, Carbon dioxide, Hydrogen, Propane and Butane to pass through this chamber with different concentrations and different operating temperatures. Sets of experimental measurements are done to detect the gas sensitivity for each sensor depending on the output volt of microcontroller, in relation to temperatures, concentration of gases, and variable resistances for each sensor. In this paper, a novel approach for the gas identification is based on the fuzzy technique. The identification rules are directly extracted from the data driven from the microcontroller in the form of (IF-Then rules), where membership functions are employed in the fuzzy classifier. The results of the fuzzy logic are shown to provide gas identification according to variation in different parameters, such as gas concentrations variation in sensor's resistance and output volt of microcontroller at different temperatures and to indicate that the selection of different gases is possible, based on microcontroller, which improves sensitivity and selectivity with high accuracy and reliability.

Keywords-: Gas detection, fuzzy logic, intelligent sensing, Gas sensors, ZigBee.

1. Introduction

Analysis and monitoring of gases can be carried out by means of metal oxide gas sensors, which are used for either health or safety hazards. It is preferable to combine the response of a set of different sensors to achieve more measurement accuracy than using an individual sensor. This resembles the system known as electronic noses. In order to correct the nonlinearities, low selectivity and other problems of a single sensor, the multi sensors data fusion are used to combine data to perform inference that may not be possible from a single sensor alone. Thermal conductivity has been the analytical method based on the fact that various gases differ considerably in their ability to conduct heat. The most common methods used for gas analysis involves the use of a hot wire thermal conductivity gas analysis cell as illustrated in figure (1). Such a cell consists of two chambers, each containing a wire filament. One chamber allows the sample gas to flow through it, while the other is sealed and contains a reference gas, such as air. The bridge is calibrated by allowing the same gas to surround the two filament resistors, reference filament and measuring filament, R3 and R4. The resistor R2 is adjusted to yield a balanced bridge condition. Then the gas in the measuring chamber is replaced by the gas under test with the same pressure, and temperature conditions. If the test gas has different thermal conductivity than the reference gas, the measuring filament resistors R4 will be cooled at different rate. A different cooling rate results depending on a change of the temperature of the measuring filament resistor R4 and so change in its resistance. The change in resistance R4 causes the unbalancing of the bridge. The condition of unbalance actuates a meter which indicates the change in composition of the gas . The whole approach is based on measurements taken from an experimental set up with certain typical commercial sensors.

The outputs of sensors are monitored by a microcontroller, and then a proper intelligent processing using fuzzy logic has been chosen because it gives better results and enhances discrimination techniques among sensed gases.

Fuzzy logic systems encode human reasoning to make decisions and control dynamical systems. Fuzzy logic comprises fuzzy sets which are methods of representing non statistical uncertainty and approximate reasoning, including the operations used to make inferences. It is a tool for mapping the input features to the output, based on data in the form of "IF - Then" rules. An implementation of a fuzzy expert system depends on Mamdani type fuzzy controller. The objective of the controller is to discriminate different gases and to detect the concentration of each gas according to the input variables.

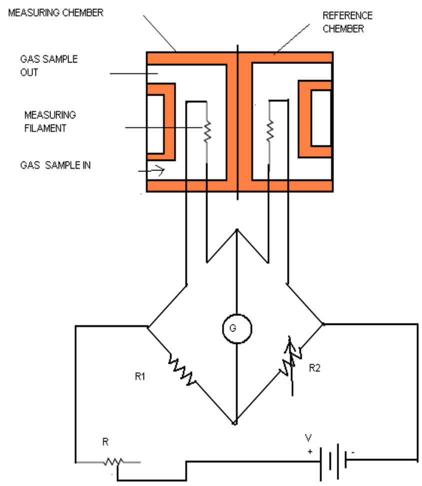

Fig. 1 Thermal conductivity Gas Analyzer circuit.

2. STEPS TO CONSTRUCT A FUZZY CONTROLLER

There are five steps to construct a Mamdani type fuzzy controller:

Step 1:

Identify and name the input linguistic variables and their numerical ranges. There are three input variables which are temperature, output volt of microcontroller, and the variable resistance related to each sensor. There are five ranges for each variable, which have been identified.

Temperature (CO)
Linguistic Range
Low 20<R<30
Moderate 25< T < 35
Medium 30 < T < 40
High 35<T<45
V.high 40<T<50

Output volt (v)
Linguistic Range
V. Low 0.5 <V< 1.5
Low 1 < V < 2
Medium 1.5 <V<2.5
High 2 < V < 3
V. High 2.5<V<3.5

Variable Resistance (kQ)
Linguistic Range
V.Low 1<RL<3
Low 2<RL<4
Medium 3 < RL < 5
High 4 < RL < 6
V. High 5 < RL < 7

Step 2:

Identify and name the linguistic output variable and it's numerical ranges. There is one output variable, which has been identified the concentration of each gas in (ppm).

The concentration of each gas in (ppm).

Linguistic Range

V. Low 1OO<concentration<400
Low 250<concentration<550
Medium 400<concentration<700
High 550<concentration<850
V. High 700<concentration<1000

Step 3:

Define a set of fuzzy membership functions for each of the inputs and the output, variables. The low and high values are used to define a triangular membership functions. The height of each function is one and the function bounds do not exceed the high and low ranges listed above for each range. The membership functions must cover the dynamic ranges, related to the minimum and maximum values of inputs and output that represents the universe of discourse.

Step 4:

Construct the rule base that will govern the controller's operation. The rule base is represented as a matrix of inputs and output variables. At each matrix row different input variable ranges with one of the output variable range. All rules were activated and fired in parallel whether they were relevant or not and the duplicate ones are removed to conserve computing time. Each rule base is defined by ANDing together with the inputs to produce each individual output response, for example: If temperature is low AND, if volt is low AND if RL is low THEN concentration is low.

Step 5:

The control actions will be combined to form the excited interface. The most common rules combination method is the centroid defuzzification to get the crisp output value. This step is a repeated process, after all adjustments are made, which allows the fuzzy expert system to be able to discriminate and classify the data set patterns of the different gases.

3. Overview of ZigBee.

Currently, there are various wireless technologies available, for instance Bluetooth, Infrared (IR), ZigBee, Radio Frequency (RF) and etc. Radio frequency (RF) module is a wireless device that basically works on either 413 MHz or 315 MHz frequency. Basically, the module doesn't contain any protocol and it will broadcast the signal with no security included. RF only supports star topology and the wireless range can cover up to 100 meters. Bluetooth is a wireless technology that had been introduced 10 years ago for short-range communication. Bluetooth technology is developed to be used in Personal Area Network (PAN) network for low power communication between devices such as phones, personal computers (PC), Personal Digital Assistance (PDA) and etc [1]. The range for Bluetooth wireless device can be up to 10 meters with 2.5mW (4dBm) power consumption. Bluetooth operates in unlicensed Industrial Scientific-Medical (ISM) band at 2.4 GHz with the capability of frequency hopping [1] and it only supports star topology communication. ZigBee is a protocol that had been developed based on Open System Interconnection (OSI) layer model. It builds on IEEE standard 802.15.4 which defines the physical and Medium Access Control (MAC) layers. ZigBee supports three types of communication topologies; star topology, tree topology and mesh topology. ZigBee wireless device operates with very-low power consumption which makes it the most attractive wireless device to use in Wireless Sensor Network (WSN). ZigBee has multi-hop communication capability, hence providing an unlimited range of communication.

ZigBee promises robust and reliable, and self-configuring networks that provides a simple, cost-effective and battery efficient application. These allow the technology to take advantage of short-range wireless protocol, flexible mesh networking, strong security tools, well-defined application frame works, and a complete inter operability . Therefore, in this project, ZigBee wireless modules chosen to be used for establishing communication between all devices (sensor nodes) in the controller house with the main computer.
Table 1 shows comparison between several wireless technologies and their respective specifications and applications.

Table 1. Comparison of specifications of existing wireless technologies

	ZigBee / IEEE 802.15.4	WLAN / IEEE 802.11b/ag	Bluetooth 1.2
Application focus	Monitoring & Control	Web, Email, Video	Cable Replacement
Stack Size (kBytes)	< 64	> 1000	> 250
Battery Life (days)	100 – 1000 +	0.5 - 5	1 - 7
Network Size (#nodes)	~Unlimited (65536)	Many	7
Bandwidth (kbps)	250	11 000 / 54 000	~1000
Range (meters)	100 +	100	10 +
Target BOM cost	$ 3	$ 9	$ 5

4. SYSTEM MODEL.

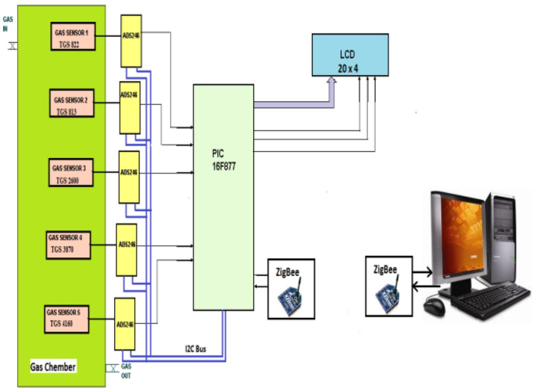

Fig (2) The block diagram of hardware implementation of gas sensing detector system

Description of parts of the system:

1. Gas Sensors

For the identification of gases, five commercial gas sensors TGS 822, TGS 813, TGS 2600, TGS 3870 and TGS 4160 from "Figaro" sensors industry have been used with heating supply voltage equal to 5V.

2. Gas chamber & gases used:

Proposed mechanism consists basically of the gas bottle mass flow controllers, sensor chamber with volume 475cm3, and heating system. Gases used in the experiment are Carbon dioxide, Hydrogen, Methane, Propane, and Butane. All measurements taken for specific humidity.

3. Microcontroller (PIC16F877).

Microcontroller is used to sense the analog voltage from gas sensors & to convert into digital. it is also used for serial transmission of data for processing & analysis to PC.

4. Programmable resistor (AD5246).

For resistance variation five variable resistances are require to connected in series to the five sensors placed out of chamber. In manual variable resistance every time we require varying the five resistances at every gas detection reading it consume lot of time in detection of gas. so we use i2c based digital programmable resistor AD5246. Followed by the microcontroller, to control and monitor the output of each sensor.

5. ZigBee:

For wireless Transmission it is used. It establish the wireless communication between controller to computer for data transfer.

6. PC:

For data processing & identification using fuzzy logic & display the identified gas concentration pc is used. Pc is used for fast data processing, the values of A & B are already stored in pc with reference to all five gas sensors for various load resistance & for various gases. This identifies of various gas concentration in chamber. Using software we also store the database of gas concentration after every decided time period.

7. LCD:

For display the result of identified gas in ppm the LCD module 16x2 is used in our project.

5. WORKING OF SYSTEM MODEL.

All sensors are connected as an array and covered by a chamber, which has "in" and "outlet" ports. The input is connected with the mass flow controllers to control the concentration of input gas after purging with humidified air. All sensors are subjected to variation in temperatures from ambient temperatures and up.

The output of microcontroller is monitored and recorded every 20 sec. Different gases concentrations are applied 1O0ppm, 400ppm, 700ppm, 1OOOppm with different environmental temperatures between 40C to 100C with different variable resistances for each sensor RL=1K, 3k, 5k and 7k to control the rate of adsorption of gases inside the sensor .

Figure (2) shows the block diagram of gas sensing system detector. The block diagram of the hardware requirements for the system implementation includes a microcontroller PIC 16F877. It is chosen for the implementation of this task due to the on-chip memory resources, as well as its high speed. The output data is transferred to a

PC via a ZigBee wireless network from microcontroller.

We will develop the in C language and then compile , assemble, and down-loaded to the system. The program consists of three parts: measurement part, mathematical analysis part, and presentation part. The system is supported by a collection of methods to improve the uncertainty and reliability. Different processing techniques like self calibration, self validation are merged to test and evaluate the performance of the whole measuring system in order to minimize errors.

6. METHOD OF ANALYSIS

After the experiment has been setup and data have been collected, data analysis has been done by using two methods. The first method: Find the relation between the sensors output volt with the temperature for each gas at different concentrations. This relation has been extracted using curve fitting which proved to be the best when using exponential function, that accordingly gives prediction to the nearest output volt measured in the experiments with the least error. The output volt of sensor under different values of operating temperature can be calculated by the exponential equation.

V= AxeBT

Where:

V: Is the output volt of microcontroller.

T Is the temperature °C.

A and B : Are variable coefficients of fitting.

The values of A and B are depend upon different concentrations, variable resistances, and type of gas.

The second method: Via the fuzzy controller depending on the temperature, output volt of each sensor and the variable resistance as inputs to give online prediction of different concentrations for each gas as the output. The feature of each gas is detected, based on the fuzzy system.

7. CONCLUSION

An experimental measuring system based on a microcontroller has been developed. All experimental data are performing in a fully automated computer control.

Different gases are used such as Methane, Carbon dioxide, Hydrogen, Propane and Butane with different concentration.

The microcontroller based gas sensing measurement system that is presented in this seminar. It is fabricated as a unit prototype. In this seminar, the analysis method of all sensors sensitivity for a specific gas is a result of the output volt variations depending on each variations of temperature. A wide range of measurements of data had been recorded at a long period of time. Then the averages of their selected results were taken. By applying the fitting method on each curve, the exponential equation is predicted for all extracted curves. Mamdani type fuzzy controller is used to construct the rules, which are extracted from the data driven from the microcontroller.

It can be used to discriminate and classify the data set patterns for different gases according to the variation in different parameters, such as gas concentrations, variation in sensor's resistance and output volt to microcontroller at different temperatures and to improve the sensor's selectivity for gas identification. Due to the abundant number of membership function figures, the results were limited to representing the fuzzy logic output surface for each sensor. Fuzzy logic gives on line prediction of the concentration depending on the behavior of each gas with different sensors which are extracted from the experiments.

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