The Fifteenth International Symposium on Artificial Life and Robotics 2010 (AROB 15th '10),
B-Con Plaza, Beppu,Oita, Japan, February 4-6, 2010

Multisensor Fusion Based Gas Detection Module

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Abstract: The paper develops a gas detection module for the intelligent home. The module uses many sensors to detect environment of the home and building. The gas sensors of the module have a NH3 sensor, an air pollution sensor, an alcohol sensor, a HS sensor, a smoke sensor, a CO sensor, a LPG sensor and a nature gas sensor, and can classify more than eight type gases using multisensor fusion algorithms. In the logical filter method, we can use AND or OR filter to be implemented in the gas detection module. Then we can calculate the system reliability of AND filter and OR filter, and classify the gas type in the environment. The controller of the gas detection module is HOLTEK microchip. The module can communicate with the supervised computer via wire interface or wireless RF interface, and caution the user by the voice module. Finally, we present some experimental results to measure unknown gas using the gas detection module on the security system of the intelligent building.

Keywords: intelligent home, multisensor fusion algorithms, logical filter method**.**

I. INTRODUCTION

An intelligent building system (IBS) is the integration of various services, and contains security system, building heating, ventilating and air-conditioning (HVAC) technologies, computer system, tele-communication and Internet. The most important role of the intelligent building is security system. How to build the security system? It is an important issue for the intelligent building. In the security system, redundant and complementally information results can enhance system reliability and certainty using multisensor fusion method, and use module based structure to make it easy to operation. To develop module based security devices is a important working for human life. In generally, it is most important to detect harmful gas in the security system of the home automation. We want to develop a intelligent gas detection module to decrease the dangerous event for intelligent building.

A gas detection module is an instrument comprising an array of chemical sensors to be combined in a board, and a pattern recognition system that is embedded in the controller to classify the gas [1]. The gas detection system plays an important role in the in many fields, e.g. environmental protection, production safety, food surveillance, intelligent transport system and life support system for manned spaceship [2,3,4]. To classify a single gas of the environment, a variety of pattern recognition technologies have been applied to the gas detection system. The most important ones are principlal component analysis (PCA), cluster analysis (CA). and discriminate function analysis (DFA) [5,6]. Meanwhile, quantitative data processing techniques such as multiple linear regression (MLR) and artificial networks (ANN_S) are also used to quantify the gas concentration [7].

The paper is organized as follows: section II describes the system structure of the gas detection system for home automation, and explains the functions of the gas detection module. Section III explains detection algorithms of the gas module, and presents the user interface of the gas detection system. Section IV presents the experimental results of the gas detection on three variety conditions using the module for the home security system. The brief concluding comments are described in Section V.

II. SYSTEM ARCHITECHTURE

The architecture of the gas detection system is shown in Fig. 1. The system contains a gas detection module, a master module, a supervised computer and a pair of wireless RF interface. The main element of the gas detection system is gas detection module. The module has eight gas sensors. There are a NH3 sensor, an air pollution sensor, an alcohol sensor, a HS sensor, a smoke sensor, a CO sensor, a LPG sensor and a nature gas sensor. The master module will convert the communication protocol from I2C to RS232, and transmits the signals to the supervised computer via

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wire interface, and transmits the signals to the supervised computer via wireless RF interface, too.

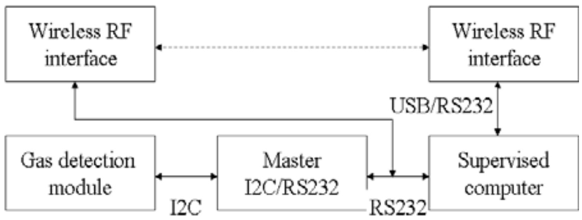
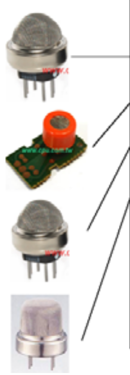


Fig. 1. The architecture of the gas detection system

In the gas detection module, we use many gas sensors that measure an unknown gas to be listed in Fig. 2. The HS133 and HS134 sensor elements have high sensitive, long life, reliable stability and good selectivity to low carbon monoxide concentration. The HS135 sensor element has long period stability and widely detecting scope. It should be suitable for detecting of smoke, SO2, CO2, isobutene, alcohol, etc. The sensor element HS129 can detect isobutene, propane, alcohol and hydrogen, and the resistance value changing will be cause by different gas concentration.

The sensor element HS130A can fast response and high sensitivity for alcohol, and the resistance value changing will be different base on different concentration alcohol. The sensing element of TGS826 is a metal oxide semiconductor which has low conductivity in clean air. In the presence of a detectable gas, the sensor's conductivity increase depending on the gas concentration in the air. The TGS826 has high sensitivity to ammonia gas.



tern	Sensors	Type
1	HS sensor	TGS825
2	Alcohol sensor	HS130A
3	NH_3 sensor	TGS826
4	Air pollution sensor	HS135
5	CO sensor	HS134
6	LPG sensor	HS133
7	Nature gas sensor	HS131
8	Smoke sensor	HS129

Fig. 2. The sensor type of the gas detection module

Fig. 3 shows the basic structure of the gas detection module. Each sensor i of the gas detection module output s a measurement value x_i in the presence of an input unknown gas j. Where $i = 1,2,3,\ldots n$ and n denotes the number of the sensor in the array. Regard r_{ij} as the pre-processed response data. The patter recognition method combined with or without the knowledge database is used to execute the gas class prediction and component analysis, where y_i denotes the predicted gas output for the unknown gas.

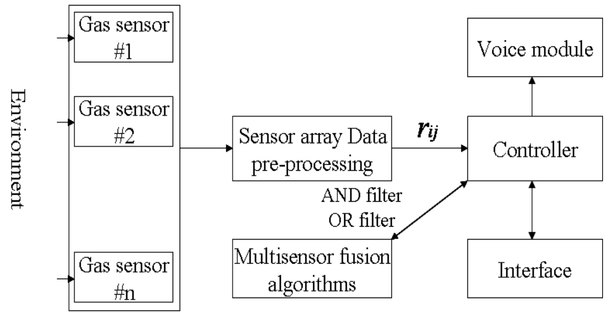


Fig. 3. The structure of the gas detection module

The prototype of the gas detection module is shown in Fig. 4. The gas detection module contains four levels and a fan. There is sensor level, driver level, control level and power level. The sensor level has eight gas sensors to be aligned in a board. The shape is shown in Fig. 5. Next level is pre-processing circuits for these gas sensors. The level has two boards, and the functions of the board are the same. The control level contains a HOLTEK microchip, a voice module and a wireless interface. The power level can convert AC power to DC power. The level provides DC power to each level. The fan can decrease the temperature of the gas detection module. It sucks wind from the sensor level of the module.

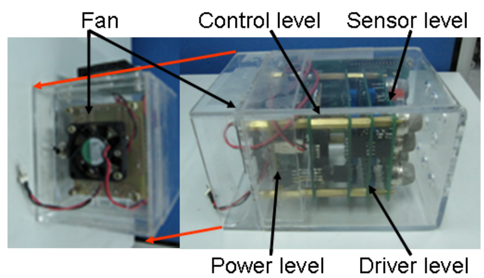


Fig. 4. The prototype of the gas detection module

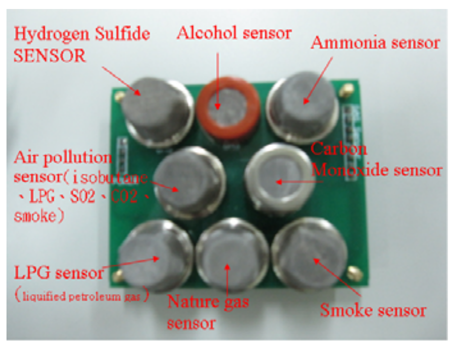


Fig. 5. The sensory arrangement of the module

III. DETECTION RULE

In the detection algorithms, we use logical filter method to classify the unknown gas in the module. In the logical filter method, we can use AND or OR filter on the gas detection module. Then we can calculate the system reliability of AND filter (R_S) and OR filter (R_P).

$$R_S = \prod_{i=1}^{n} R_i(t) \tag{1}$$

$$R_P = 1 - \prod_{i=1}^{n} [1 - R_i(t)] \tag{2}$$

R_i is the reliability of each sensor of the gas detection module. We can compare the reliability values using R_S and R_P for each unknown gas (CO, alcohol,… etc.), and decide which unknown gas to be found. How to implement the proposed method in the unknown gas? We measure the values (critical values) on the full concentration of the each sensor for any gas. We can define the critical values r_{ijf}, and calculate the value R_i for each sensor on the unknown gas.

$$R_i(t) = \frac{r_{ij}}{r_{ijf}} \tag{3}$$

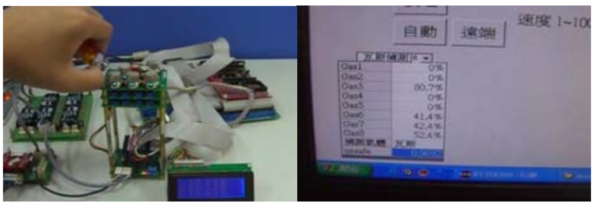
For example, in the gas detection module, we can use sensor elements HS135, HS133, HS131 and HS129 to detect nature gas concentration of the environment, and compare these measurement values. We can use the logical filter method to decide the gas reliability to be over the critical value. In the other condition, we can use HS130A, TGS826 and HS133 sensors to detect alcohol concentration to be over the threshold using the same method, too.

The gas detection module interface of the supervised system is shown in Fig. 6. The user interface can acquire detection results from many detection modules, and display on the monitor of the supervised computer. The monitor has many regions to display the information from these detection modules. The upper of the left side can display fire signal (A1), power status (C3), environment measured value (A2), two axes compass signal and acceleration value (C1 and C2). The upper of the right side can display power measured value. The bottom of the left side can control the mobile robot forward, backward, turn right, turn left and stop. Users can speed up and slow down to the mobile robot (D1 and D2), too. The bottom of the right side can display the status of obstacle. It can display the two layer measured values for sixteen ultrasonic sensors (B2) and sixteen IR sensors (B1) [8]. In the paper, we are intered in the region A3. It can display the measurement concentration of the gas sensors, and classify the gas type using the proposed method on the bottom. The right side of the region A3 can display the reliability values for each detection gas.

Fig. 6. The architecture of the gas detection system

IV. EXPERIMENTAL RESULTS

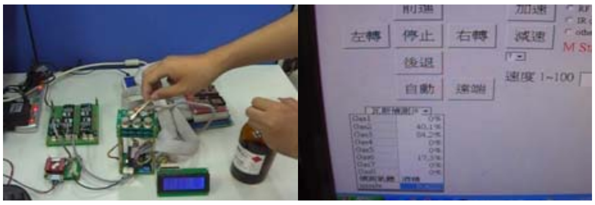
We use the gas detection module to detect three variety gases. First the gas detection module detects the gas leakage of the building. The experimental result is shown in Fig. 7(a). we can see the concentration of these gas sensors #3, #6, #7 and #8 to be about 80%, 41%, 42% and 52%, and the consistence of these gas sensors #1, #2, #3 and #4 to be 0%. That is to say, the gas sensors #1, #2, #3 and #4 can not detect gas. The decision output display gas leakage using the proposed algorithm. The experimental result is shown in Fig. 7(b).



(a) Gas detection (b) User interface

Fig. 7. The experimental result of the gas detection

Then we use the gas detection module to detect another gas (alcohol). The experimental result is shown in Fig. 8(a). we can see the concentration of these gas sensors #2, #3 and #6 to be about 40%, 84% and 19%. and the concentration of these gas sensors #1, #4, #5, #7 and #8 to be 0%. That is to say, the gas sensors #1, #4, #5, #7 and #8 can not detect gas. The decision output display alcohol gas. The experimental result is shown in Fig. 8(b).



(a) Alcohol detection (b) User interface

Fig. 8. The experimental result of the alcohol detection

Finally, we use the gas detection module to detect CO gas. The experimental result is shown in Fig. 9(a). we can see the concentration of these gas sensors #2, #3, #5 and #6 to be about 26%, 68%, 89% and 13%, and the concentration of these gas sensors #1, #4, #7 and #8 to be 0%. That is to say, the gas sensors #1, #4, #7 and #8 can not detect CO gas. The decision output display gas leakage. The experimental result is shown in Fig. 9(b).

(a) CO detection (b) User interface

Fig. 9. The experimental result of the CO detection

VI. CONCLUSION

We have designed a gas detection module using eight chemical gas sensors for the security system of the intelligent building. The gas detection module can measure many gases using multisensor fusion algorithms, and can transmit the detection results to the supervised computer via wire/wireless interface. The controller of the gas detection module is HOLTEK microchip, and speaks the measurement status on real-time using voice module. In the experimental results, the module can detect three variety gases using multiple gas sensors. In the future, we want to develop multisensor fusion algorithms to detect more and more gas by the gas detection module, and revise the proposed algorithms to enhance the accuracy, and use the module to be applied in other fields. There are intelligent mobile robot, intelligent transport system and hospital.

ACKNOWLEDGMENT

This work was supported by the National Science Council of Taiwan, R. O. C. under Grand NSC 98-2622- E-224-030-CC3.

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