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Develop a Multi Interface Based Detection Module for Home Automation

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Abstract

The security and appliance of building, home is essential, to human life. A unlucky event was often caused by the negligence of humans. We have developed a multi interface based security system for **home automation**. The structure of the security system is divided into five modules. Each module has two variety interfaces (wireless and series RS232). There are fire detection and diagnosis module, intruder detection and diagnosis module, environment detection module, power detection and diagnosis module, and application control module. In the application control module, we use two-wire communication method through wireless and **GSM** interface. First, we implement these methods using computer simulation and achieve quite satisfactory results. Finally, we design the hardware module using these methods for home automation.

Keywords：**home automation, GSM**

1. Introduction

Intelligent buildings can provide safety, convenience and welfare for society in the 21st century, and allow effective management of resource with minimum life-time costs at the same time. 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 (Figure 1), telecommunication and Internet. The most important components is building security in an intelligent building. In the security system, redundant and complementally information results can enhance system reliability and certainty of intelligent building using mulisensor fusion method. In generally, the home automation is a part of the intelligent building. The most important of the home automation is the security system. The appliance control is not negligent.

Wang and So [1] presented the history of development of building automation system (BAS). The structure of features of a modern BAS was introduced and future trends of BAS are discussed. Azegami and Fujiyoshi [2] described a systematic approach to intelligent building design. Kujuro and Yasuda [3] discussed the systems evolution in intelligent building. The quality of building services can be enhanced by updated information processing and communications functions of building automation systems. Finley et al. [4] presented a survey of intelligent building and reviews issues such as system perspective, subsystem services, multi-tenant building. Flax [5] discussed components and cost benefits of the intelligent building. Chung and Fu expect to set up the standard of appliances and communication protocols, and propose a complete system architecture with integrate control kernel to construct an intelligent building system [6, 7].

The paper is organized as follows: section 2 describes the system overview of the security and appliance control system for home automation. Section 3 explains detection principles and diagnostic methods for the module of security system and appliance control system. Section 4 devotes the hardware structure of the implementation system, and Section 5 presents the simulation experimental results for the proposed methods. The brief concluding comments are described in Section 6.

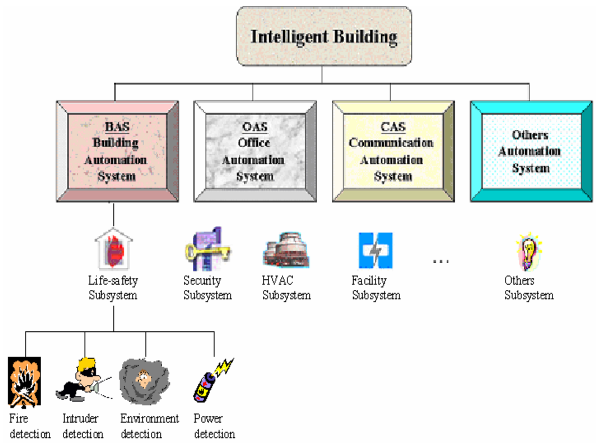


Figure 1. Intelligent Building Architecture

2. System Overview.

We propose distributed structure security system for home automation system based on the multi-models fusion architecture. In the security system, there are fire detection/ diagnosis module, intruder detection/diagnosis module, environment detection module and power detection/diagnosis module. We use two smoke sensors, two flame sensors and two temperature sensors to detect fire happened and diagnose fault sensors. In the intruder subsystem we use IR sensor, proximity sensor and touch sensor to detection intruder and diagnose fault sensor. In the environment module, we use humidity sensor, illumination sensor, gas sensor and voice sensors to detect environment variable. Finally, we use some current sensors to detect power state, and we list these sensors in Table I.

Table I. Sensors for security system

Agent	Sensors
Fire detection /diagnosis module	Two smoke sensors, Two flame sensors, Two temperature sensors
Intruder detection/ diagnosis module	Touch sensor, magnetic sensor, IR sensor, body sensor.
Environment detection module	humidity sensor, illumination sensor, gas sensor, voice sensor
Power detection/diagnosis module	Four current sensors.

The overview of the security system and appliance control is shown in Figure 2. In the architecture, there are five modules in the system. These modules are independent and autonomous, and can work concurrently, each module can transmits the sensory data, parameter values and detection results to the main controller（IPC） through wireless series interface(RS232). And transmits detection results to the mobile phone using GSM module, too. The auxiliary module can receives the detection and diagnosis results from each module, and transmits the signal to the GSM module. In the other way, the module can transmit the signal to GSM module using series interface, too.

The security system communicates with mobile phone using GSM (Global System for Mobile) modular. The GSM modular (WMOD2) was made by Wavecom.. The modular is a seft-contained E-GSM900/GSM1800 (or E-GSM900/GSM1900) dual band module.

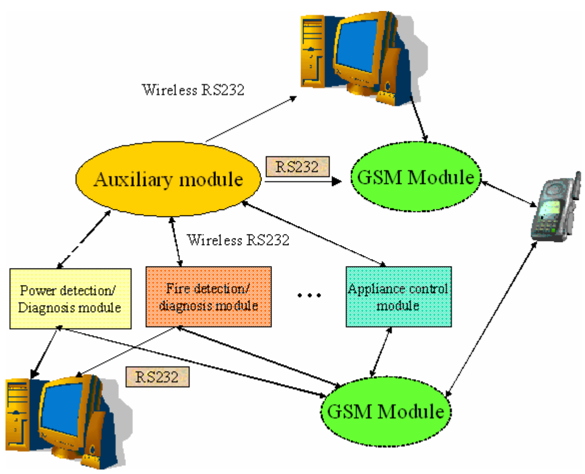


Figure 2. the system overview

3. Detection Methods.

3.1. Fire Detection Method

We use adaptive fusion method [8, 9, 10] to detect fire event and diagnosis sensor error. First, we use six sensors for the fire detection. These sensor have two smoke sensors (S1 and S2), two flame sensors (F1 and F2) and two temperature sensors (S1 and S2). These sensors are classified into two groups. Each group has one smoke sensor, one flame sensor and one temperature sensor. We use adaptive fusion method in each group for fire detection (shown in Figure 3), and compare the weight variance for each group for sensory error detection and isolation [11, 12]. We can get the new update rule is:

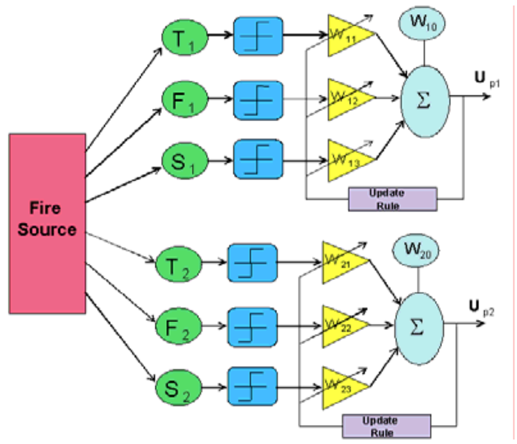


Figure 3. Adaptive multisensor fusion architecture

$$\Delta W_i = \begin{cases} \dfrac{1}{m_{1i}} & \text{If } Ui=+1 \text{ and } H_1 \\ \dfrac{1}{m_{0i}} & \text{If } Ui=-1 \text{ and } H_0 \\ -\dfrac{1}{m_{1i}}\displaystyle\sum_{k=0}^{\infty}\dfrac{(W_i+W_0)^k}{k!} & \text{If } Ui=+1 \text{ and } H_0 \\ -\dfrac{1}{m_{0i}}\displaystyle\sum_{k=0}^{\infty}\dfrac{(W_i-W_0)^k}{k!} & \text{If } Ui=-1 \text{ and } H_0 \end{cases} \quad (1)$$

$$\Delta W_0 = \begin{cases} \dfrac{1}{m} & \text{when } H_1 \text{ occurs} \\ -\dfrac{1}{m}\displaystyle\sum_{k=0}^{\infty}\dfrac{W_0^k}{k!} & \text{when } H_0 \text{ occurs} \end{cases} \quad (2)$$

3.2 Intruder Detection Method

We use rule-based method to detection intruder and diagnosis sensor error. First, we use touch sensor, magnetic sensor, IR sensor and body sensor to detect intruder. The detection and diagnosis rule is shown in Figure 4. The detection rule of the intruder system has four levels. The high level uses touch sensor to detect intruder. If the touch sensor detect intruder, the output state is “Yes”, otherwise, the output state is “No”. We use magnetic sensor to detect intruder in the second level. In the third level, we use IR sensor to detect intruder. In the low level, we use body sensor to detect the intruder. Four variety sensors can decide four variety results. They are intruder, intruder and sensor fault, sensor fault and normal, and can diagnose which sensor will be error.

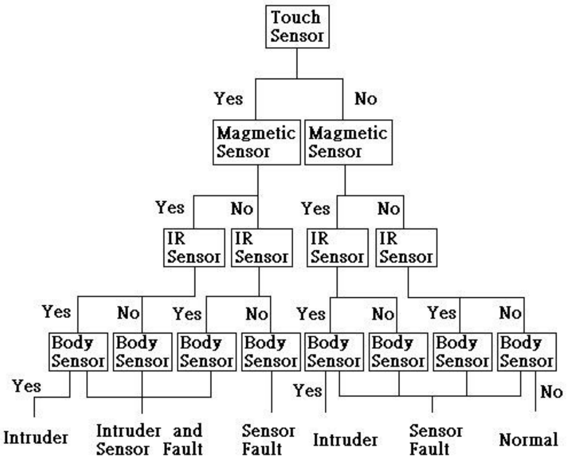


Figure 4. The detection and diagnostic rule of the intruder system

3.3Environment Detection Method

The environment function contains humidity detection, illumination detection, gas detection and voice detection. The environment information can be extracted using approaches based on statistical signal detection theory.

We modeled the observed system as the sum of three signal components, to be shown in equation (3).

$$Z(t) = W(t) + n(t) \qquad (3)$$

Where:

Z(t) : The matrix of parameter by the environment system as measured or observed.

W(t): The matrix of parameter by the environment system under ideal condition, e. g, no noise or temperature fluctuation.

n(t) : Any signal changes as a consequence of thermal effects, sample error, etc.

If the signal is deterministic and the noise is Gaussian with zero mean, then the measurement value is adequate:

$$w(t) = (1/N)\sum_{i=1}^{N} Z_i(t) \qquad (4)$$

3.4 Power Detection Method

The adaptive fusion method is developed for binary hypothesis testing case. That is to say when signal is absent, we define H_0. Otherwise, we define H_1. But the measured signal is analog. The method is not adequate to detect and diagnose sensory state. So we use the redundancy management method for detection and isolation of faulty sensors [13].

The redundant measurements of a process variable are modeled as

$$m = Hx + \varepsilon \qquad (5)$$

Where m is the m_i vector of measurements that are generated from sensors, H is the measurement matrix of dimension (l×n) and rank n, and x is the true value of the n-dimensional measured variable. The vector ε represents measurement errors such that, for normal condition of each measurements, $|\varepsilon_i| < b_i$, where b_i is the specified error bound for the measurement m_i.

For scalar measurements, the measurement matrix in (5) can be chosen as $H = [1,1,\ldots 1]^T$, without loss of generality, for a pair of scalar measurement m_i and m_j, the (m_i- m_j) value can be compare with the sum ($b_i + b_j$) of the respective error bounds for a consistency check. Any two scalar measurements m_i and m_j at the sampling instant K are defined.

$$\begin{cases} |m_i(k) - m_j(k)| \le [b_i(k) + b_j(k)] & \text{consistent} \\ |m_i(k) - m_j(k)| > [b_i(k) + b_j(k)] & \text{Inconsistent} \end{cases} \qquad (6)$$

In this context, the inconsistency index of a measurement m_i is defined at a given sample time as

$$I_i = \sum_{j=1}^{k} f\left[|m_i - m_j| > (b_i + b_j)\right] \quad i = 1,2,\ldots k \qquad (7)$$

Where the indicator function f is defined as

$$f[*] = \begin{cases} 0, & \text{If * is false} \\ 1, & \text{If * is true} \end{cases} \qquad (8)$$

4. *Hardware design*

The hardware structure of the fire detection and diagnosis module is designed using microprocessor. The microprocessor performs computation of modified adaptive fusion method. In general, We must process the measurement signal to convert to standardize voltage output (0V~+10V) by amplifier circuit. The relations of input sensory signals and output voltage signals must be linear by tuning the calibration circuits. Finally, these sensory signals that convert to binary digital signals transmit to microprocessor by comparison circuits. The microprocessor is MCS-51 series products. These computations of modified adaptive fusion method deal with by using assembly language of microprocessor. The modular of fire detection is shown in the figure 5.

The on-line power detection and diagnosis modular is shown in Figure 6. The size of the power detection and diagnosis modular is 8cm×8cm×10cm (L×W×H). The modular can display the each measurement value using 20×4 LCD modular, and fuse an exact measurement value using the redundant management method, and also diagnosis which sensor to be faulty. The modular can transmits measured value and sensory state to the main controller using series interface (RS232), and transmits the detection results to GSM module using two-wire communication.

The intruder detection and diagnosis module is shown in Figure 7. the right side of the module is IR source. The IR receiver is embedded in the left module. In the module, it contains four variety sensors to detect intruder. The controller is microprocessor (ATMEL 89C2051). The size of the module is 8cm× 8cm × 8cm(L×W×H). The microprocessor can acquires sensor signal to decide a adequate output using the detection rule.

The controller of the appliance control module is microprocessor, too. The module can receive the wireless signal to control the appliance, and transmits the result to the source using wireless interface. The appliance module can finish the same work using GSM module, too. That is to say, the user can uses mobile phone to control the appliance, and display the results on the mobile phone panel using GSM module. The appliance control module is shown in Figure 8.

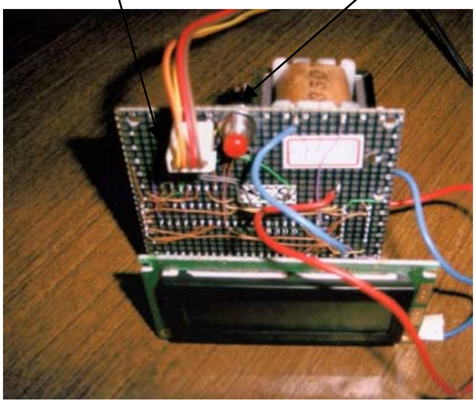


Figure 5. The fire detection modular

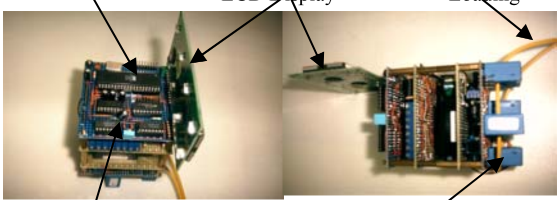


Figure 6. The on-line detection and diagnosis modular.

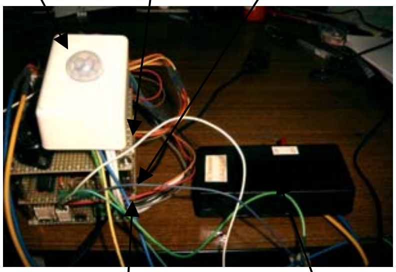


Figure 7. The intruder detection and diagnosis modular

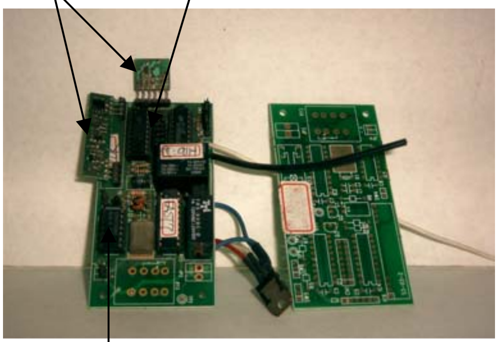


Figure 8. The appliance control modular

5. Experimental Results.

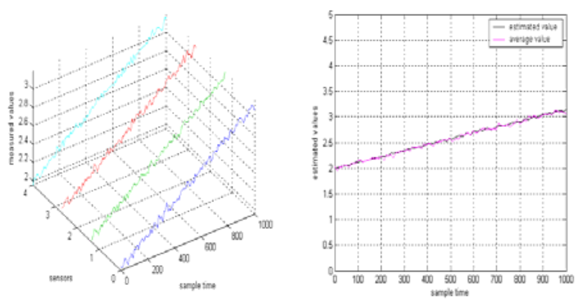
In the fire detection system of intelligent building, we use 6 sensors to detect fire occurrence and diagnose fault sensors. The experimental results indicate that the adaptive fusion method is a suitable solution for fire sensor fault detection and isolation [12]. In the intruder detection/subsystem module, we use rule-based method to detect toe intruder and diagnose sensor error. The fire detection module and intruder detection module can transmit the decision results to mobile phone through the GSM module. The experimental results are shown in Figure 9. The accuracy of the method is over 95%.

In the power system, we use four AC type current sensors to detect the current variety of home automation. In this paper, we assume that a priori of all sensors are the same, and we use computer simulation for four cases. Case I is all sensors are consistent, Case II is two measurements m_1 and m_2 and faulty, simultaneously and identically, (m_1, m_2) and (m_3, m_4) are two consistent pairs, and they are mutually inconsistent. Case III is two measurements m_1 and m_4 faulty simultaneously and identically. Case IV presents m_1, m_2, m_3 and m_4 to be mutually inconsistent.

The experimental results are shown from Figure 10 to Figure 13. In the Figure 10, the four sensory measurements are normal. We can say four sensors to be consistent. Then we can calculate $\hat{x}$. Figure 10-(a) is four measured values for case I. Figure 10-(b) is the estimate value and average value for case I. Next, if two sensory measurements $m_1$and m_2 are fault simultaneously and identically. (m_1, m_2) and (m_3, m_4) are two consistent, and they are mutually inconsistent. That is to say, the three fault sensors may make the gain of the amplifier and calibration circuits a bias. Then the method is fail, we can't acquire an exact estimate value, and we calculate the average value. These results are shown in Figure 11.

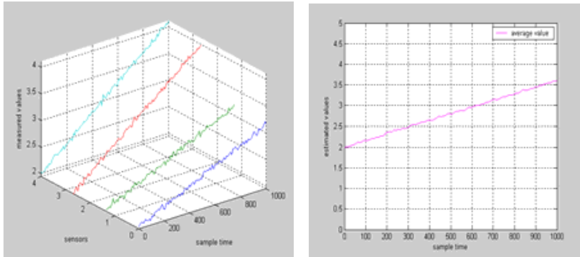
Figure 12 presents the experimental results for Case III. The case III is m_1 and m_4 fail and unidentifiable, That is to say, the sensor m_1 may be suddenly broken, or the connected line is floating. The proposed method may diagnose and isolate the error sensor and estimate an exact measured value. Figure 12-(a) is four measured values for case III , and Figure 12-(b) is the estimate value and average value using equation (8) for case III . In the case IV, m_1, m_2, m_3 and m_4 are mutually inconsistent, and then the proposed method is fault. So that the exact estimate value is not exist. These experimental results are shown in Figure 13.

(a) fire detection (b) intruder detection
Figure 9.The display panel of mobile phone

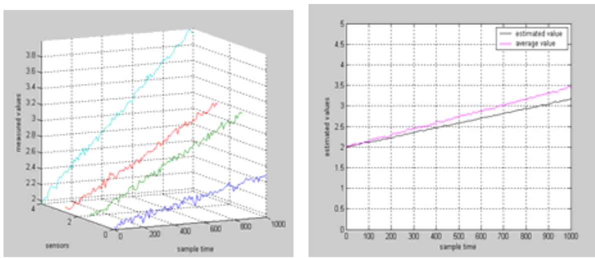


(a) The four measured values. (b) The estimate value.

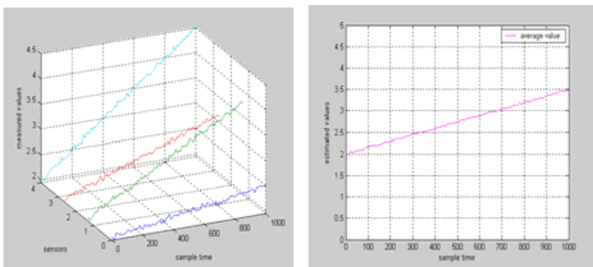
Figure 10. The experimental results for Case I



(a) The four measured values. (b) The average value.
Figure 11. The experimental results for Case II



(a) The weight measured values. (b) The estimate value and average value
Figure 12. The experimental results for Case III



(a) The four measured values. (b) The average value.
Figure13. The experimental results for Case IV

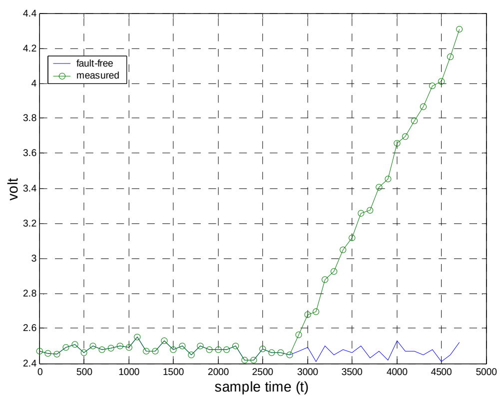


Figure 14. The measurement values

We use statistic method for environment detection and diagnostic method. In the experiment, we suppose the sensor to be not suddenly fault, and the input signal is ramp function. We use sampling time is 5000 in the simulation experiment and the fault condition is happened from 3000 to 5000. Figure 14. presents the measurement values between fault-free state and sensor error state for ramp input. The threshold (λ_t) is over 0.5 about sampling time 3000. (Figure 15). We can say the method is nice for environment detection module of the home automation.

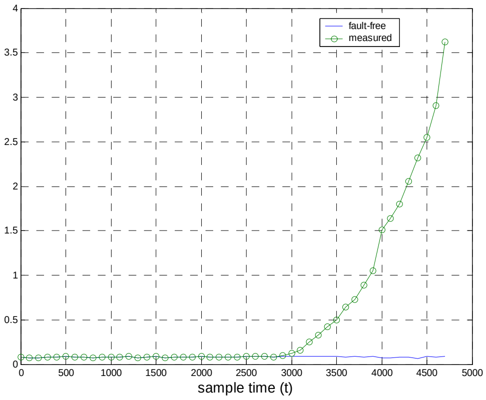


Figure 15. The threshold values

5. Conclusion

We have presented a multi interface based detection module that is applied in home automation. The security system contains four detection modules and one application control module. The detection modules have fire detection and diagnosis module, intruder detection and diagnosis module, environment detection module and power detection and diagnosis module. There are four methods (adaptive fusion method, rule based, statistic method and redundancy management method)be applied in status detection and sensor fault diagnosis. Then we implement these methods using computer simulation, and achieve nice results. Then we design the hardware structure using the four detection and diagnosis methods. The detection and diagnosis subsystem can transmit the detection and diagnosis results to the user through GSM modular, too. In the future, we want to supervise these detection and diagnosis modules through Internet.

Reference

[1] C. W. Wang and A. T. P. So, "Building Automation In The Century," in proceedings of the 4-th International Conference on Advance on Advances in Power System Control, Operation Management, APCOM-97, Hong Kong, November 1997, pp.819-824.

[2] M. Azegami and H. Fujixoshi, "A systematic Approach to Intelligent Building Design," IEEE Communications Magazine, October 1993, pp.46-48.

[3] Kujuro and H. Yasuda, "Systems Evolution in Intelligent Building," IEEE Communication Magazine, October 1993, pp.22-26.

[4] Marion R. Finley, Jr. Ancilla Karajura and Raphael Nbogni, "Survey of Intelligent Building Concepts," IEEE Communication Magazine, April 1991, pp.18-20.

[5] M. Fiax, "Intelligent Building," IEEE Communication Magazine, April 1991, pp.24-27.

[6] W. Y. Chung, L. C. Fu and S. S. Hung, "A Flexible, Hierarchical and Distributed Control Kernel Architecture for Rapid Resource Integration of Intelligent System", IEEE International Conference on Robotics Automation, Seoul, Korea, May 21-26, 2001, pp.1981-1987.

[7] L. C. Fu and T. J. Shih, "Holonic Supervisory Control and Data Acquisition Kernel for 21st Century Intelligent Building System", IEEE International Conference on Robotics and Automation, San Francisco CA, April 2000, pp.2641-2646.

[8] N. Ansari, J. G. Chen, Y. Z. Zhang, "Adaptive Decision Fusion for Unequiprobable Sources", IEE Proceedings Radar, Sonar and Navigation, 1997, PP. 105-111.

[9] N. Ansari, E. S. H. Hou, Bin-Ou Zhu and Jiang-Guo Chen, "Adaptive Fusion by Reinforcement Learning for Distributed Detection Systems", IEEE Transactions on Aerospace and Electronic Systems, 1996, Vol. 32 NO. 2, PP. 524-531.

[10] G. Chen and N. Ansari, "Adaptive Fusion of Correlated Local Decision", IEEE Transaction on System, Man and Cybernetics-PART C: Application and Review, Vol.28, No. 2, May 1998.

[11] R.C.Luo, K.L.Su and K.H.Tsai, "Intelligent Security Robot Fire Detection System Using Adaptive Sensory Fusion Method", Internation Conference of the IEEE on Industrial Electronics Society ,2002 (IECON 2002).

[12] R.C.Luo, K.H.Tsai and K.L.Su, "Fire Detection and Isolation for Intelligent Building system Using Adaptive Sensory Fusion Method", Proceedings of the IEEE International Conference on Robotics and Automation,Vol. 2002,PP.1777-1781.

[13] Ren C. Luo, **Kuo L. Su** and Chi W. Deng "Power Supply Diagnosis System Using Redundant Sensor for Intelligent Security Robot", IEEE International Conference on Industrial Electronic, Control, and Instrumentation (IECON'2003), PP2500-2506。