Detection System of Security Robot Using Multisensor Fusion Algorithms

Ting-Li Chien[1], Jyh-Hwa Tzou[2], Chun-Chieh Wang[3], Kuo-Lan Su[4]

1. Department of Electronic Engineering, Wu-Feng Institute of Technology, Taiwan
2. Department of Mechanical Engineering, Wu-Feng Institute of Technology, Taiwan
3. Department of Electronic Engineering Chienkuo Technology University, Taiwan
4. Department of Electrical Engineering, National Yunlin University of Science & Technology, Taiwan
E-mail: cdl@mail.wfc.edu.tw sukl@yuntech.edu.tw

Abstract: The paper develops detection system of the module based intelligent security robot that has uniform interface. The detection system contains power detection module、 gas detection module、 environment detection module and fire detection module. The control unit of these modules is HOLTEK microchip. These modules can communicate with master module using I2C interface. The master module communicates with main controller of the security robot using RS232 interface. The main controller of the security robot system is industry personal computer (IPC). It can display status of these modules on the monitor. These modules can enhance the detection results using multisensory fusion algorithms. The user can add or remove the detection modules in any time, and the main controller can acquires sensor signals from these detection modules on real-time. Finally, we present some experimental results using these detection modules, and integrate these modules in the robot system that executes some scenario.
Keywords: module based robot system**,** I2C, robot

I. INTRODUCTION

With the robotic technologies development with each passing day, robot systems have been widely employed in many applications. Nowadays, robot systems have been applied in factory automa Recently, more and more research takes interest in the robot which can help people in our daily life, such as service robot, office robot, security robot, and so on. In the future, we believe that robot will play an important role in our daily life.

In the past literatures, many experts research in the security robot. Some research addressed in developing target-tracking system of mobile robot [1,2], such as Hisato Kobayashi et al. proposed a method to detect human being by an autonomous mobile guard robot [3]. Yoichi Shimosasa et al. developed Autonomous Guard Robot [4] witch integrate the security and service system to an Autonomous Guard Robot, the robot can guide visitors in daytime and patrol in the night. D. A. Ciccimaro developed the autonomous security robot – "*ROBART III*" which equipped with the non-lethal-response weapon [5, 6]. Moreover, some research addressed in the robot has the capability of fire fighting [7, 8].

The hardware and software of these robots are complexity, and are not easy to maintain and repair. How to operate these robots is very difficult for the user. The development and adaptability of robot systems have limited. To increase their development and adaptability, the concept of the module-based robot system (MBRS) has been studied in the robotic field since 1980s. Many robot systems have been designed [9-12].

The paper is organized as follows: Section II describes the system architecture and the interface of the detection system for the module based intelligent security robot. Section III explains the function of the detection module, and it describes the fusion algorithms of the detection module. Section IV presents the experimental results for these detection modules and user interface. Section VI presents brief concluding remarks.

II. SYSTEM ARCHITECTURE

The system architecture of the module based intelligent security mobile robot is shown in Fig. 1. The module based security robot has three parts. There are detection system, motion control system and others. We are focus on the detection system in the paper. The interface of the master module and detection modules is Inter IC (I2C). The master module connects with some detection modules. These modules can use two-way communicate with master module, and the master module communicate with the main controller of the mobile robot by series interface (RS232). These modules are connecting with the master module, and the master can detect which module to be connected, and transmit the module ID to the main controller. On the other hand, the user can adds and removes the module from the mobile robot system. The master can detect which module will be added and removed, and transmit the module ID to the main controller. The main controller of the module based intelligent security robot can know how much modules on line and it can acquire data from these modules.

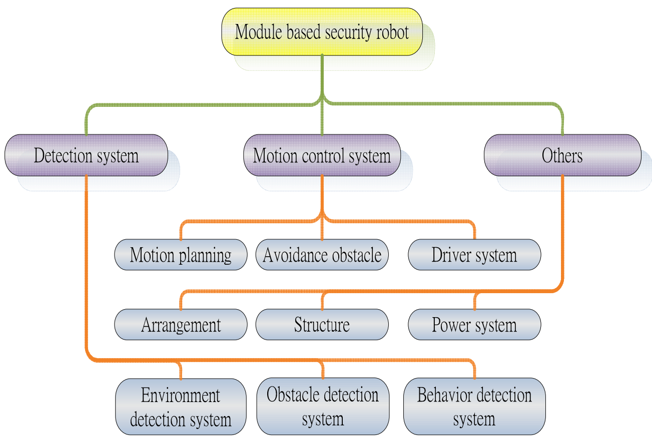

Fig. 1 The system architecture

The controller of these modules is HOLTEK microprocessor. The detection modules have fire detection module, environment detection module, gas detection module, remote IR and wireless RF module, power supply module, compass module, acceleration module, power detection module, inclement detection module, obstacle detection module (IR sensors and ultrasonic sensors), master module and DC servomotor driver module. We arrange an ID to each module, and identify the module function by the ID. These modules can be equipped in the intelligent mobile robot. The prototype of the module based intelligent mobile robot is shown in Fig. 2.

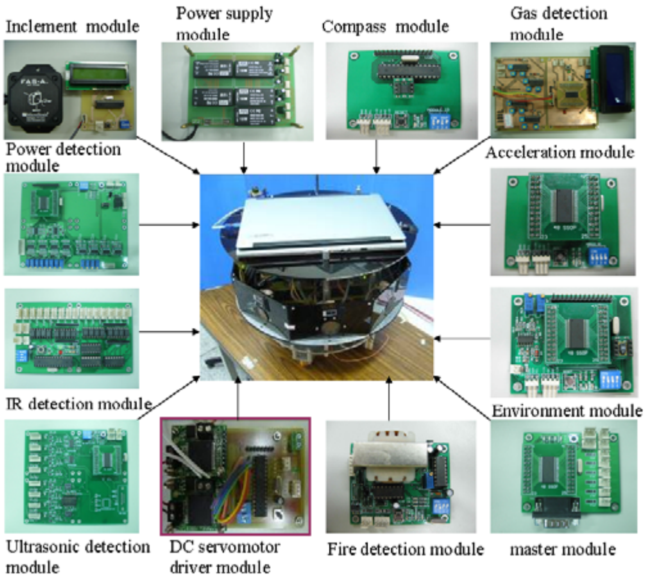

Fig. 2 The prototype of the module based intelligent robot

These modules can acquire sensory signal and processes these signal using amplifier and calibrate circuits and transmits sensory data to the master module using I2C interface. We list these sensors of the detection modules to be tabulated in Table 1.

Table 1 Sensors in these detection modules

Module	Sensors	Examples
Environment detection module	humidity sensor	SHT1x
	temperature sensor	SHT1x
	illumination sensor	S1133
Fire detection module	Flame sensor	R2868
Power detection module	Current sensor	LA-55P
Gas detection module	Carbon monoxide sensors	HS-134 TGS203
	Air pollution	HS135
	Alcohol sensor	TGS822
	Gas sensor	TGS800

III. DETECTION MODULES

The detection system of the module based intelligent mobile robot has some detection modules and one master module. These detection modules contain Environment detection module 、Fire detection module、Power detection module and Gas detection module. Some of the detection modules can calculate the exact measured value using multisensor fusion algorithm, and transmit measured values and decision output to the master module using I2C interface. The controller of these modules is HOLTEK microchip.

- **Power detection module**

In the power detection module, we use four current sensors to measure the current variety of the module based security robot. The block diagram of the power detection module is shown in Fig. 3. The module can measure current and voltage values on the power variety of mobile robots. We use two multisensor fusion methods (redundant management method and a statistical prediction method) to detect current sensor and voltage signals status. In the redundant management method, we can get an exact measured value for power detection, and isolate faulty signal from current sensor and voltage signal [13, 14]. Then we can calculate the residual power of the mobile robot, and decide the residual time to work using second-order polynomial regression for the mobile robot [15].

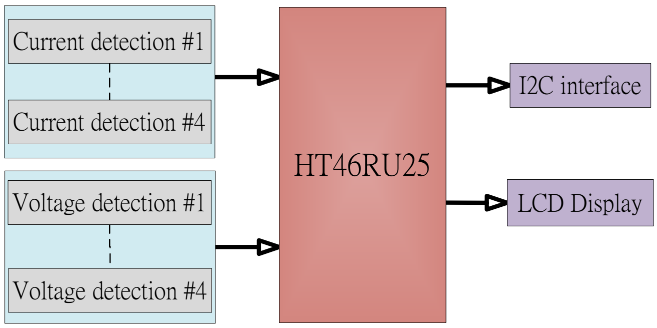

Fig. 3 The block diagram of the power detection module

In the intelligent power detection module, we use redundant management method to estimate the exact values on current and voltage on the power of the mobile robot. The value of the measured parameter is obtained by the following equation at that sample time k

$$\hat{x}(k) = \frac{\sum_{i=1}^{l} m_i(k) I_i(k_i)}{\sum_{i=1}^{l} I_i(K)} \quad (1)$$

Where I_i is a weighted value for the each measurement m_i at the given sample time k. So we can define indicator function Ii is

$$Ii = \sum_{j=1}^{l} f\left[\left|m_i(k) - m_j(k)\right| \le \left(b_i(k) + b_j(k)\right)\right] \qquad i = 1,2,\cdots l \quad (2)$$

$$f[*] = \begin{cases} 1, & if \quad * \quad is \quad true \\ 0, & if \quad * \quad is \quad false \end{cases} \quad (3)$$

In the redundant management method and statistical signal method, we can get an exact measured value for power detection, and isolate faulty signal from current sensor and voltage signal. Then we want to predict the residual power of the mobile robot. First we must fit the curve from the power detection value of the mobile robot. Next the user can set the critical power value for the mobile robot. The main controller of the mobile robot can calculate the extrapolation value from the critical power value, and can calculate the residual working time for the mobile robot. The mobile robot must move to the charging station in the residual time.

In the paper, we fit a second-order polynomial regression using the power estimated value.

$$y = a_0 + a_1 x + a_2 x^2 + e \tag{3}$$

The sum of the squares of the error is

$$S_r = \sum_{i=1}^{n} (y_i - a_0 - a_1 x_i - a_2 x_i^2)^2 \tag{4}$$

To generate the least squares fit, we take the derivative of Equation (4) with respect to each of the unknown coefficient (a_0, a_1 and a_2) of the polynomial, and we can get

$$\begin{aligned} na_0 + (\sum x_i)a_1 + (\sum x_i^2)a_2 &= \sum y_i \\ (\sum x_i)a_0 + (\sum x_i^2)a_1 + (\sum x_i^3)a_2 &= \sum x_i y_i \\ (\sum x_i^2)a_0 + (\sum x_i^3)a_1 + (\sum x_i^4)a_2 &= \sum x_i^2 y_i \end{aligned} \tag{5}$$

Finally we can calculate $a_0, a_1,$ and a_2 using numerical analysis method from Equation (5). Then we set the power critical value to be P_S and

$$a_2 x^2 + a_1 x + a_0 = P_S \tag{6}$$

We can calculate the x value (the unit is second) from Equation (6). The sample time of the power system is 1 second.

- **Gas detection module**

In the gas detection module, there are two carbon monoxide sensors (HS134 and TGS203), air pollution sensor (HS135), alcohol sensor (TGS822) and gas sensor (TGS800). The HS134 and TGS203 sensor elements have high sensitive, long life, reliable stability and good selectivity to low carbon monoxide concentration. The TGS203 has low sensitivity to alcohol and hydrogen. The HS135 sensor element has long period stability and widely detecting scope. It should be suitable for detecting of smoke, SO2, CO2, isobutance, alcohol, etc.. The sensing element of the sensor TGS822 is a tin dioxide (SnO2) semiconductor which has low conductivity in clear air. It has high stability and reliability over a long period, and high sensitivity to organic solvent vapors. The block diagram of the gas detection module is similarity to Fig. 3.

We can use sensor elements HS134 、 TGS203 and HS135 to detect CO_2 density of the environment, and compare these measurement values. We can use the logical filter method to decide the CO_2 density to be over the threshold. In the otherwise, we can use TGS822 and HS135 sensors to detect alcohol density to be over the threshold using the same method, too. 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)

$$R_S = \prod_{i=1}^{n} R_i(t) \tag{7}$$

$$R_P = 1 - \prod_{i=1}^{n} [1 - R_i(t)] \tag{8}$$

$R_i(t)$ is the reliability of each sensor of the gas detection module.

- **Environment module**

The environment detection module contains humidity detection, illumination detection and temperature detection. The sensor element of the humidity and temperature detection is SHT1x, and the sensor element of the illumination is S1133. The environment information can be extracted using equation (9) to (12). The humidity measurement value is RH_{true}, and the temperature measurement value is T. The module can be applied in smart home and greenhouse, too.

$$T_C = 0.01(SO_T) - 40 \tag{9}$$

$$RH_{linear} = -0.28 \times 10^{-6} (SO_{RH})^2 + 0.0405(SO_{RH}) - 4 \tag{10}$$

$$RH_{true} = (T_C - 23)(0.01 + 0.00008(SO_{RH})) + RH_{linear} \tag{11}$$

$$T = -40 + 0.04(SO_T) \tag{12}$$

IV. EXPERIMENTAL RESULT

In the power detection module, we use redundant management method and statistical prediction method to calculate the exact power [14, 15]. Then we can compute the standard deviation of each sensor to find out the error sensor for the module. If the standard deviation is bigger than threshold, we can say the current sensor to be broken. We must isolate the measured value of the current sensor, and replace it with other current sensor.

Now in the power detection module, the measured value of current sensor #4 to be broken. We can see the standard deviation (145.9) is bigger than threshold, and the standard deviation is bigger than others. We can diagnose the current sensor to be broken, and we can isolate the measured value. The experimental result is shown in Fig 4. Finally we can use these measured values of the other current sensors (#1, #2 and #4) to calculate the exact current value.

In the residual power prediction experiment, the user can set the critical power. The proposed method can calculate the residual time, and the power of the mobile robot down to the critical value.

In the Fig. 5, the user set the critical power to be 26 W. first, the mobile robot can fit the second-order curve using polynomial regression method. Then it can compute the residual time, display on the bottom of the monitor.

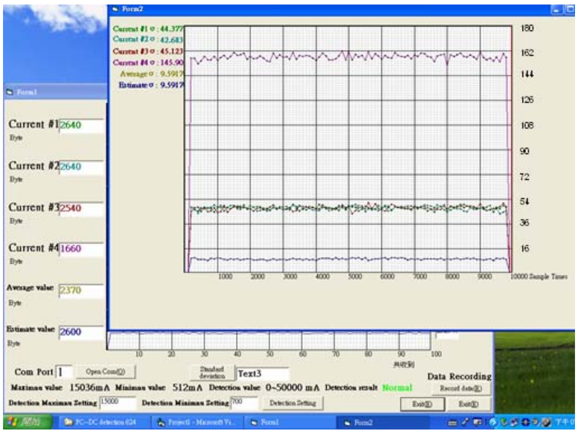

Fig. 4 The standard deviation variety of case II

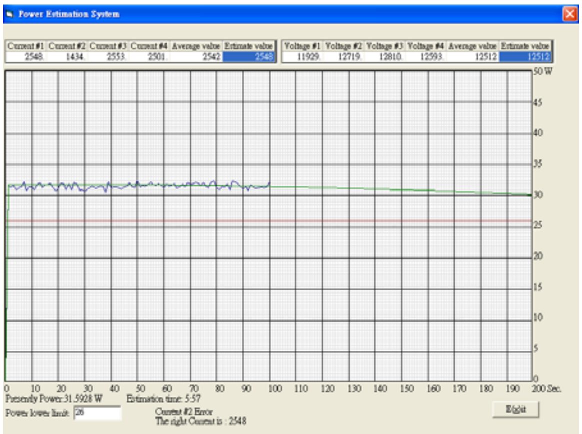

Fig. 5 The residual power prediction for 26W

V. CONCLUSION

We have presented a module-based security robot. These modules have environment module, fire detection module, gas detection module, master module and power detection module. The controller of these modules is HOLTEK microchip. we want to develop multisensor fusion algorithms to enhance the detection results through these detection modules. In the power detection module, we use redundant management method and statistical signal detection method to isolate faulty sensor, and estimates a exact current detection value for mobile robot. The module can transmits really current and voltage values and detection results to main controller (IPC) of the security robot using series interface (RS232). The main controller of the security robot can fit a second-order polynomial curve using auto-regression method. Then the user can select the critical power value to prediction the residual time on real-time for the security robot moving in free space.

ACKNOWLEDGMENT

This work was supported by the National Science Council of Taiwan, R. O. C. under Grand NSC 97- 2221- E-224-071-.

.

REFERENCE

[1] S. O. Lee, Y. J. Cho, M. H. Bo, B. J. You and S. R. Oh , "A stable target-tracking control for unicycle mobile robots," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, (IROS 2000) , Vol.3 , 2000 , pp.1822-1827.

[2] L. E. Parker and B. A. Emmons, "Cooperative multi-robot observation of multiple moving targets", Proceedings of the IEEE International Conference on Robotics and Automation,, vol.3, 1997, pp.2082-2089.

[3] H. Kobayashi and M. Yanagida, "Moving object detection by an autonomous guard robot", Proceedings of the 4th IEEE International Workshop on Robot and Human Communication, 1995, TOKYO, pp.323-326.

[4] Y. Shimosasa, J. Kanemoto, K. Hakamada, H. Horii, T. Ariki, Y. Sugawara, F. Kojio, A. Kimura and S. Yuta, "Some results of the test operation of a security service system with autonomous guard robot," 26th Annual Conference of the IEEE on Industrial Electronics Society, 2000 (IECON 2000), Vol.1, pp.405-409.

[5] Gilbreath, G. A., Ciccimaro, D. A., and H. R. Everett, "An Advanced Telereflexive Tactical Response Robot," Proceedings, Workshop 7: Vehicle Teleoperation Interfaces, IEEE International Conference on Robotics and Automation, ICRA2000, San Francisco, CA, 28 April, 2000.

[6] Ciccimaro, D. A., H. R. Everett, M. H. Bruch and C.B. Phillips, "A Supervised Autonomous Security Response Robot,", American Nuclear Society 8th International Topical Meeting on Robotics and Remote Systems (ANS'99), Pittsburgh, pp, 25-29 April, 1999.

[7] A. Bradshaw, "The UK Security and Fire Fighting Advanced Robot project,' IEE Colloquium on Advanced Robotic Initiatives in the UK, 1991, pp.1/1-1/4.

[8] Kuo L. Su, "Automatic Fire Detection System Using Adaptive Fusion Algorithm for Fire Fighting Robot," IEEE International Conference on System, Man and Cybernetics (SMC 2006), Grand Hotel, Taipei, Taiwan, October 2006, pp966-971. (EI)

[9] C. Pozna, "Modular Robots Design Concepts and Research Directions," The 5th International Symposium on Intelligent System and Information (SISY 2007), pp.113-118.

[10] Z. Dehuai, X. Gang Z. Jinming and L. Li, "Development of a Mobile Platform for Security Robot," Proceeding of the IEEE International Conference on Automation and Logistics, pp.1262-1267.

[11] Z. M. Bi and S. Y. T. Lang, "General Modular Robot Architecture and Configuration Design," Proceeding of the IEEE International Conference on Mechatronics & Automation, pp.268-273.

[12] E. Edwan and R. Fierro, "A Low Cost Modular Autonomous Robot Vehicle," Proceeding of the 38th Southeastern Symposium on System Theory, pp.245-249.

[13] R. C. Luo, K. L. Su and C. W Deng,"Power Supply Diagnosis System Using Redundant Sensor for Intelligent Security Robot," IEEE International Conference ON Industrial Electronic, Control,and Instrumentation(IECON2003),PP.2500-2506

[14] Ren C. Luo, Kuo L. Su, "Multilevel Multisensor Based Intelligent Recharging System for Mobile Robot," IEEE Transaction on Industry Electronic. Vol.55, No.1, January, 2008, pp.270-279.

[15] Kuo L. Su Jyh H. Tzou and Chien C. Liu, "Development of a Multisensor-Based Residual Power Prediction System for Mobile Robots," IEEE Workshop on Advanced Robotics and its Social Impacts 2007 (ARSO '07), Hsinchu, Taiwan, December 9-11, 2007, pp.114-119.