Multi-robot Based Intelligent Security System

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Abstract: The article develops a multiple security modules based intelligent security system that has multiple communication interfaces to be applied in home automation. The interfaces of the intelligent security system contain wire RS485, wireless RF and Internet. The detection modules of the system have active security modules and passive security modules. The passive security modules contain wire security modules and wireless security modules. The control unit of all security modules is HOLTEK microchip. Each security module has two variety interfaces. They use voice module to alarm users for event condition, and transmit the real-time event signals to the supervised computer via wire RS485 or wireless RF interface. If the event occurrence, the supervised computer calculates the belief values using Dempster-Shafter evidence theory according to the passive wire and wireless security modules. The belief value is over the threshold. The supervised computer controls the mobile robot moving to the event location, and receives the signal from the mobile robot via wireless RF interface, and recognizes the final decision output using Dempster-Shafter evidence theory, and displays detection and decision output values on the monitor of the user interface. Finally, we present some experimental results using wire passive security modules, wireless passive security modules and active security modules on the fire detection and gas leakage detection using the platform of the intelligent security system.

Keywords: home automation**,** wire RS485, wireless RF, Internet, HOLTEK microchip, Dempster-Shafter evidence theory

I. INTRODUCTION

Intelligent buildings and home can provide safety, convenience and welfare for human living in the 21st century, and control and manage resource with minimum life-time costs. An intelligent building system (IBS) is the integration of various systems. They contain 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. In generally, the security system contains supervised system, active security modules, passive security modules and appliance control modules, and uses redundant and complementally information fusion algorithms to enhance system reliability and certainty of intelligent building, and construct the safety network using multiple level protection.

In the past literatures, many experts research in the security system. 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, and multi-tenant 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 [5].

In recent years, mobile robots have been widely applied in the security system as the active security modules. Recently more and more research takes interest in the field especially intelligent service robot. There are some successful examples, ASIMO, KHR, QRIO, WABIAN-2R and AIBO. In our lab, we have been designed a fighting mobile robot (ISLR-I) [6] and a module based mobile robot [7]. The research field of mobile robot includes many directions, such as motion planning, vision system, self-location, speech recognition, supervised and remote supervised communication and environment detection. Yoichi Shimosasa *et al*. developed autonomous guard robot [8, 9] which integrate the security and service system, the robot can guide visitors in daytime and patrol at the night.

The paper is organized as follows: section II describes the system structure of the multiple mobile robots based intelligent security system for intelligent home. The functions of the mobile robot are described in Section III. The section IV presents the Dempster-Shafter evidence theory to be applied in the intelligent security system. Section V presents the experimental results of the system on the fire detection and gas leakage detection. The brief concluding comments are described in Section VI.

II. SYSTEM ARCHITECTURE

The system architecture of the multiple robots based intelligent security system is shown in Fig 1. The system contains three levels. There is passive detection level, active detection level and system supervised level [10]. We develop the user interface using Visual Basic language for the security system. The system supervised

level receives detection signals via wire RS485 or wireless RF interface, and control the multiple mobile robots moving to the event location via wireless RF interface.

In the architecture, there are many security detection modules and appliance control modules in the system. They are independent and autonomous, and can work concurrently. Each module of the security system can transmits the measurement values, parameter values and decision results to the active security modules and the supervised computer via wireless RF interface. The active security and passive security modules can speech Chinese on real-time event status using voice module. Users can reset the critical values of these modules from the user interface of the supervised computer.

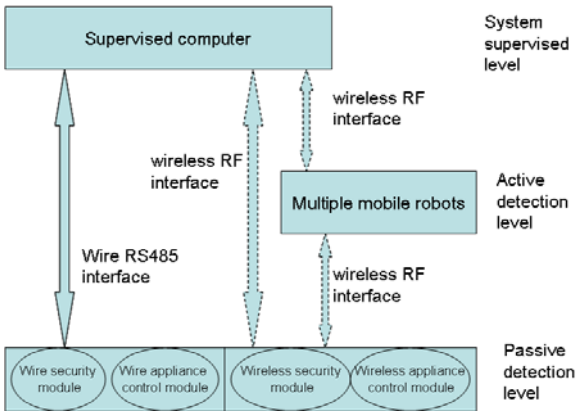


Fig. 1 The system architecture

Fig. 2 The platform of the security system

The controller of the security modules is HOLTEK microchip. These modules of the passive detection module are classified three types. There are wire security modules, wireless security modules and wire/wireless appliance control modules. The active detection level may be some remove platforms. The main device of the security system is mobile robots. We arrange an ID code in each module, and identify the module function by the ID code. The experimental platform of the multiple mobile robots based security system is shown in Fig. 2. The platform has three floors, and contains three rooms for each floor. The supervised computer controls the elevator to carry the mobile robots moving to the event location via wireless RF interface. The mobile robot communicates with the elevator via wireless RF interface, and controls the status of the elevator. Each room contains more than one wire security module, one wireless security module and one appliance control module. We arrange the same detection function security modules with wire or wireless interface on the same location enhance the detection precision using Dempster-shafter's evidence theory.

The user interface of the intelligent security system is shown in Fig. 3. The user interface contains two parts. The right side is fire detection function. The other side is gas detection function. The upper part of each side displays the image from the camera. The bottom can displays the detection and decision results from three security modules (wire/wireless security modules and mobile robot), and controls the direction of the camera using mouse. We use the green label to present no event status of the security modules, and use red label to present event status for fire or gas leakage event.

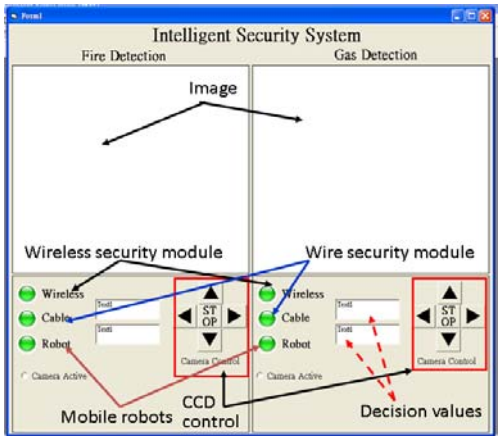


Fig 3. The structure of the mobile robot

III. MOBILE ROBOT

The mobile robot has the shape of cylinder, and it's equipped with a HOLTEK microchip as the main controller, two DC servomotors and driver devices, one compass module, obstacle detection devices, security modules (fire detection device or gas detection module), a voice module, three Li batteries and a wireless RF interface. Meanwhile, the mobile robot has four wheels to provide the capability of autonomous mobility. The mobile robot can carries variety sensors (fire or gas) moving on the platform of the security system. The structure and the hardware devices of the mobile robot are shown in Fig. 4.

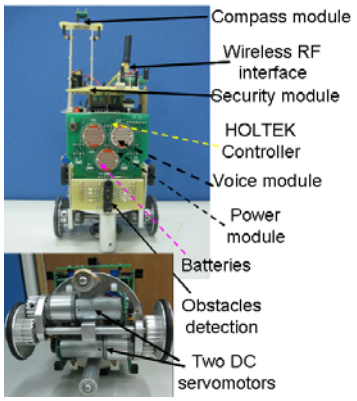


Fig 4. The structure of the mobile robot

The controller of the mobile robot can acquires the detection signal from sensors using I/O pins, and receives the command from the supervised computer via wireless RF interface, and transmits the detection signals to the supervised computer via

wireless RF interface. The detection signals are fire event or gas leakage signal. The switch input can turn on the power of the mobile robot, and selects power input to be Li batteries or adapter. The encoder of the servomotor can calculates the moving distance. We can set the pulse numbers of per revolution to be P on the wheel of the mobile robot, and the mobile robot move pulse numbers to be B. We can calculate the displacement D of the mobile robot using the equation

$$D = 4.25 \times \pi \frac{B}{P} \tag{1}$$

The diameter of the wheel is 4.25 cm. The compass module can transmits the measurement values $(x \text{ and } y)$ of two axes (X axis and Y axis) to the controller of the mobile robot. It can calculate the orientation angle θ using Eq. (2). The supervised computer can controls the direction of the mobile robot using the compass module.

$$\theta = Tan^{-1}(-y/x) \tag{2}$$

IV. ALAGORITHM ANALYZE

The development of evidence theory began in the 1960s when Dempster [11,12] developed the mathematical foundations of a two-value uncertainty mapping, upper and lower uncertainty measures, between two space. The system is satisfied the assumption with two value output on event detection. A result of this work is dempster's rule of combination, which operates on belief or mass functions as Baye's rule dose on probability functions. Shafer [13], a student of Dempster, has extended the development of belief functions and is the major proponent of evidence theory.

A brief overview of the Dempster-shafter's evidence theory is provided as follows. Let θ represents the set of hypotheses Hn , called the frame of discernment. The knowledge about the problem induces a basic belief assignment which allows to define a belief function m from 2^{θ} to [0,1] such as [14]:

$$m(\Phi) = 0 \tag{3}$$

$$\sum_{Hn \le \theta} m(Hn) = 1 \tag{4}$$

Subsets Hn of θ such that $m(Hn) > 0$ are called focal elements of m. From this basic belief assignment m, the credulity $Bel(Hn)$ and plausibility $Pl(Hn)$ can be computed using the equations:

$$Bel(Hn) = \sum_{A \subseteq Hn} m(A) \tag{5}$$

$$Pl(Hn) = \sum_{Hn \cap A \neq \phi} m(A) \tag{6}$$

The value $Bel(A)$ quantifies the strength of the belief that event A occurs. These functions (m , Bel and Pl) are derived from the concept of lower and upper bounds for a set of compatible probability distributions. In addition, Dempster -Shafer's theory allows the fusion of several sources using the Dempster's combination operator. It is defined like the orthogonal sum (commutative and associative) following the equation:

$$m(Hn) = m_1(Hn) \oplus \cdots \oplus m_M(Hn) \tag{7}$$

For two sources S_i and S_j, the aggregation of evidence for a hypothesis $Hn \subseteq \theta$ can be written:

$$m(Hn) = \frac{1}{\mathrm{K}} \sum_{A \cap B = Hn} m_i(A) \cdot m_j(B) \tag{8}$$

where K is defined by:

$$\mathrm{K} = 1 - \sum_{A \cap B = \phi} m_i(A) \cdot m_j(B) \tag{9}$$

The normalization coefficient K evaluates the conflict between two sources. An additional aspect of the Dempster-Shafer's theory concerns the attenuation of the basic belief assignment m_j by a coefficient α_j for a source S_j. For all $Hn \subseteq \theta$, the attenuated belief function can be written as:

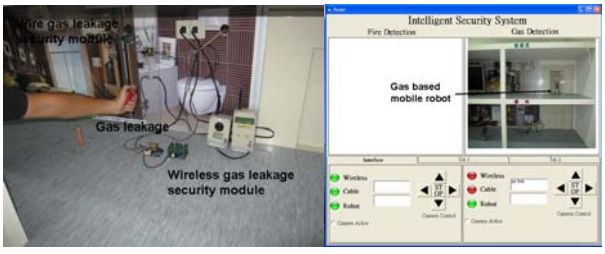
$$m_{(\alpha,j)}(Hn) = \alpha_j \cdot m_j(Hn) \tag{10}$$

$$m_{(\alpha,j)}(\theta) = 1 - \alpha_j + \alpha_j \cdot m_j(\theta) \tag{11}$$

V. EXPERIMENTAL RESULTS

In the intelligent security system, we use wire and wireless gas security modules and gas based mobile robot to detect the gas leakage on the platform. We use one lighter to provide gas on the gas leakage detection modules. The modules can transmit the detection results to the supervised computer via wire RS485 and wireless RF interface. The label of the gas security modules displays red. The experimental results are shown in Fig. 5 (a). The belief value is 0.8522 over the threshold value using Dempster-Shafter evidence theory. The experimental results are shown in Fig. 5 (b).

The supervised computer controls the mobile robot with gas detection sensor moving to the event location. The mobile robot detects the gas leakage event, and transmits the event signal to the supervised computer. The experimental result is shown in Fig. 5(c). The supervised computer receives the event signal to calculate the belief value using Dempster-shafter evidence theory to be shown in Fig. 5 (d). The value is over the threshold value, and alarm the event to users.



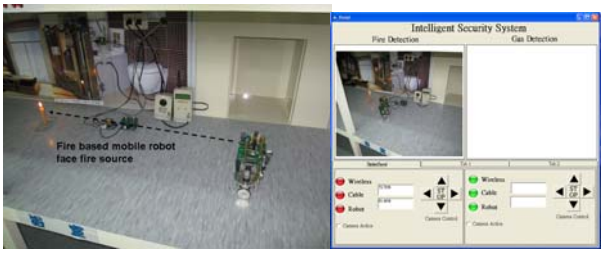
(a) (b)

(c) (d)

Fig. 5 The experimental result for gas leakage detection

Then we use wire and wireless fire security modules and fire based mobile robot to detect the fire source on the platform, too. The modules detect fire event, and transmit the detection results to the supervised computer via wire RS485 and wireless RF interface. The label of the fire security modules displays red. The experimental results are shown in Fig. 6 (a). The belief value is 0.8522 over the threshold value, and the experimental result is shown in Fig. 6 (b). The supervised computer controls the fire based mobile robot moving to the event location, and transmits the event signal to the supervised computer. The experimental result is shown in Fig. 6 (c). The supervised computer receives the event signal to calculate the belief value using Dempster-shafter evidence theory to be shown in Fig. 6 (d).

(a) (b)



(c) (d)

Fig. 6. The experimental result for fire source detection

VI. CONCLUSION

We have presented a multiple mobile robots based intelligent security system that has multiple interfaces to be applied in intelligent home. The controller of the security modules and active modules (mobile robots) is HOLTEK microchip. We use Dempster-Shafter evidence theory to enhance the detection results using passive and active security modules. The security detection modules and the mobile robots can transmit real-time event signals to the supervised computer via wire RS485 or wireless RF interface. In the paper, we use fire and gas leakage events to implement the function of the multiple mobile robots based security system for intelligent home. The experimental results are very nice to double check the event occurrence on the system. In the future, we want to increase intelligent security detection modules, and use multisensory fusion algorithm to enhance the precision of the security system, and develop remote supervised system to connect with the security system via Internet. The security decreases the false alarm condition for the event detection.

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