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Development of the Multi-detection system using Multi-sensor Fusion Algorithms

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Abstract: The paper develops the multi-detection system using multi-level surveillance structure. The system contains active detection modules, passive detection modules, a supervised computer, an image system and an intelligent home. The passive detection modules contain wire/wireless detection modules and appliance control modules, and decide the event to be true or not using fusion algorithms, and transmit detection signals to the supervised computer. Mobile robots are active detection modules and carry various sensors to search dangerous events. Each mobile robot transmits the real-time event signal to the supervised computer and the other mobile robots via wireless RF interface. The image system detects fire source using Otsu algorithm. The system integrates wire/wireless passive detection modules, mobile robots and image system to detect fire source using weighted average method. If the fire event occurrence, the supervised computer calculates the dangerous grade using logical filter method according to the signals of detection modules in the first step, and transmits the position of the fire event to the other mobile robots. The assigned mobile robots move to the event location for double check autonomously, and transmit the detection results to the supervised computer. The supervised computer gives the final decision according to the feedback signals in the second step. Finally, we present some experimental scenarios using active detection modules, passive detection modules and image recognition for the fire detection in the intelligent home.

Keywords: mobile robots, wireless RF interface, Otsu algorithm, weighted average method, logical filter method

I. INTRODUCTION

Intelligent building and home can provides safety, convenience and welfare for human living in the 21st century. The most important issue of the intelligent building is fire detection. The fire disaster hurts many people's life and brings great losses to the society in every year. Fire detection becomes more and more importance in surveillance system [1]. In generally, the measured values of the security system is redundant and complementally information, and uses fusion algorithms to enhance system reliability and certainty, and constructs the safety detection network using multiple processing protections. The multi-detection security system solves the negligence of the users. The paper proposes the multi-detection system that contains various detection modules and image system, and develops the intelligent home to implement the functions of the proposed security system.

In the past literatures, many experts research the security system of the intelligent home. Azegami [2] described a systematic approach to intelligent building design. Chung and Fu expected to set up the standard of appliances and communication protocols, and proposed a complete system architecture with integrate control kernel to construct an intelligent building [3]. Su designed multi0level security system using active detection modules and passive detection modules to detect gas leakage in the chamber [4].

In the fire detection, Ding proposed a hierarchical framework for a more efficient fire detection using modified Hidden Markov Model (HMM) [1]. Ha concentrated on the smoke detection system in video for early fire alarming using block-based smoke detection algorithm consist of three basic steps [5]. Liu used temperature, smoke concentration and CO concentration to detect fire source using multi-sensor fusion algorithm [6]. Yang used the trained (Support Vector Machine) SVM with RBF kernel and SMO algorithm to recognize image of the fire source [7].

II. SYSTEM ARCHITECTURE

The system architecture has four levels to be shown in Fig. 1. There is passive detection level, active detection level, system supervised level and remote supervised level [8]. The active detection modules are mobile robots. The robot carries various sensors to detect the environment moving in various floor of the intelligent home. The passive detection modules contain detection modules, position system and elevator system. The detection modules include wire/wireless detection modules and image system. Position system locates the position of each mobile robot moving in the intelligent home. The elevator carries mobile robots to search dangerous event in various floors. The system supervised level receives detection signals from active detection modules and passive detection modules via wire/wireless interface, and decides the event to be true or not. The remote supervised computer communicates with the supervised computer via Internet.

In the intelligent home system, there are many detection modules and appliance control modules. These modules are independent and autonomous, and work cooperation. Each detection module of intelligent home system can transmits the measurement values, parameter values and decision results to the supervised computer, and uses multi-level processing to enhance the accuracy of the event detection, and speaks Chinese language using the voice module for real-time event status.

In the active detection modules, there are more merits to use multi-robot cooperation capabilities to such a large fleet of robots. In general, the control structure of the large fleet mobile robots is classified centralized control and decentralized control. A centralized control requires robust and permanent communication capabilities between all mobile robots and the supervised system. A decentralized control only requires local communication between robots and the supervised system. Each mobile robot of the multiple robots' system will communicates with the other robots [9]. We combine the centralized control and the decentralized control in the intelligent home system.

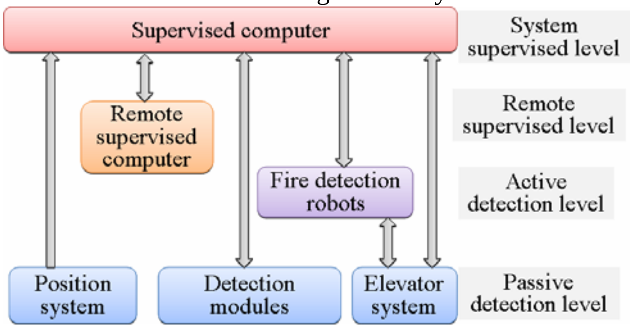


Fig. 1. The system architecture

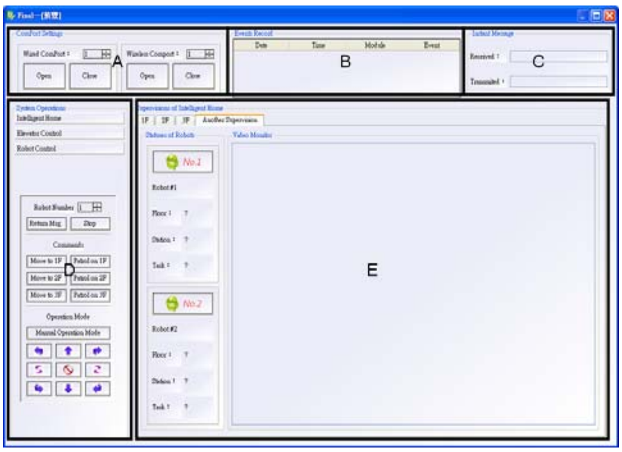


Fig. 2. User interface

The user interface of the multi-robot system is shown in Fig. 2, and contains five parts. The label "A" can programs the communication protocol between the supervised computer and the mobile robots, and sets the communication port between the supervised computer and the wire detection modules. The label "B" displays relation information from mobile robots and the wire/wireless detection modules, and records the time and location of the dangerous event. The label "C" displays the information between the supervised computer and detection modules. The label "D" can sets the threshold of the passive detection modules, control command of the elevator and mobile robots. The label "E" displays the real-time status of the intelligent home, detection signals, image signals and mobile robots, and displays the alarm position of the home.

III. DETECTION MODULES

The detection processing of intelligent home system is shown in Fig. 3, and contains active detection modules and passive detection modules. We use dash line to represent the wireless interface. The detection processing of the system has two steps. We explain the detection processing as following. In the first step, the system uses wire detection modules, wireless detection modules and image system as the passive detection modules to detect dangerous event, and uses mobile robots as the active detection modules to detect the same event simultaneously. These detection modules transmit the decision signals to the supervised computer using fusion algorithms, respectively. The supervised computer decides the event to be true or not using weighted average method. In the weighted average method, we set the same weight value for the detection signals of these modules. The decision rule is according to equation (1) and (2). Then we set a threshold value for the detection module. The average value $\bar{x}$ is over than threshold, and we can say the event to be true. Otherwise we can say no event condition. The *ith* measurements value of n sensors is presented x_i, and the weight must be satisfied $0 \le \omega_i \le 1$ is

$$\bar{x} = \sum_{i=1}^{n} \omega_i x_i \tag{1}$$

$$\sum_{i=1}^{n} \omega_i = 1 \tag{2}$$

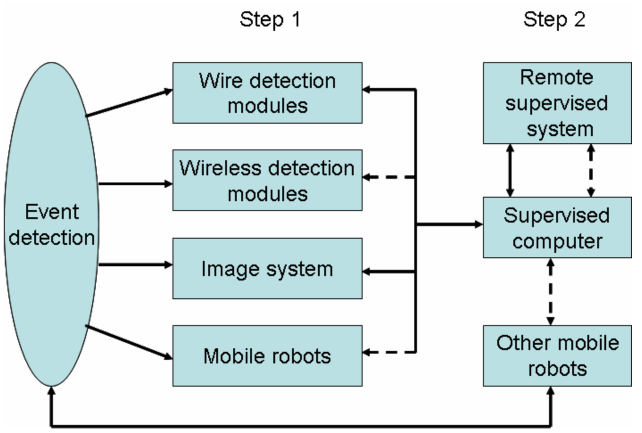


Fig 3. The detection processing

The supervised computer decides the dangerous event to be true, and controls other mobile robot moving to the event position for the second step, and transmits the event signal to the remote supervised computer, too. The main role of the active detection modules is mobile robots. The mobile robot is equipped with a microchip (HT46RU25) as controller, and calculates the movement distance from the pulse numbers of the encoder, and uses the compass module and the IR distance module to compute the orientation and the relation distance from the elevator and the wall.

The mobile robot has the shape of cylinder, and uses IR receiver to locate the position of the elevator. The position system uses IR sensors to decide the location of each mobile robot, and communicates with the mobile robot through the supervised computer. the mobile robot knows the real-time location via wireless RF interface. The mobile robot can communicate with the others robot and the supervised computer via wireless RF interface, and knows the location of each mobile robot, too.

We use flame sensor (R2686) in the passive fire detection module. Flame sensors look for characteristic emissions of either infra-red or ultra-violet light from the flames. Its peak wavelength is 220 *um* and sensing wavelength is 185~260 *um*. The R2868 has wide angular sensitivity (directivity) and can reliably and quickly detect weak ultraviolet radiations emitted from flame due to use of the metal plate cathode. It can detect the flame of a cigarette lighter at a distance of more than 5 m. The R2868 is well suited for use in flame detectors and fire alarms, and also in detection of invisible discharge phenomena such as corona discharge of high-voltage transmission lines. We use three flame sensors to detect fire source, and use the same reliability value to decide event. The block diagram of the fire detection module is shown in Fig. 4. We use logical filter method to compute the reliability of the fire detection module. The AND filter has been applied could then be expected to correspond to significant aspects of the environment. In a similar manner, an OR filter could be used to reliably segment an image because all of the sensory information would be available for use in the segmentation process. In the logical filter method, we can use AND or OR filter on the fire detection module. Then we can calculate the system reliability of AND filter (R_S) and OR filter (R_P)

$$R_S = \prod_{i=1}^{n} R_i(t) \tag{3}$$

$$R_P = 1 - \prod_{i=1}^{n} [1 - R_i(t)] \tag{4}$$

$R_i(t)$ is the reliability of each flame sensor of the fire detection module. We can use the modules to integrate the fusion results of passive detection modules and active detection modules, and get the high accuracy of the security detection.

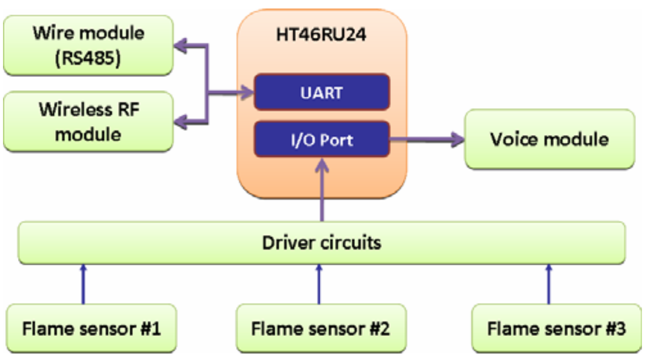
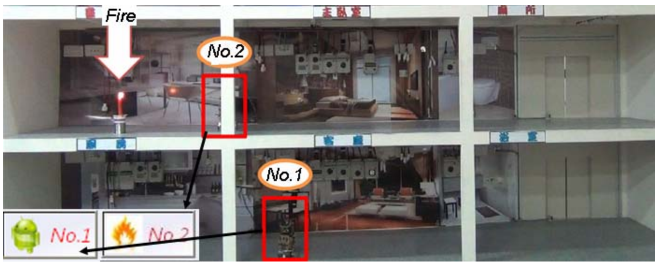


Fig 4. Block diagram of the fire detection module

IV. EXPERIMENTAL RESULTS

We use the fire detection processing to implement the security system of the intelligent home. We use passive fire module, image system and fire based mobile robots to detect fire sources in the intelligent home. We use the candle to represent the fire source. The intelligent home contains some passive detection modules, image system (outside), a supervised computer and two mobile robots. One is moving in the first floor (No. 1); the other is moving in the second floor (No. 2).

(a)



(b)

(c)

Fig. 5. The experimental result of fire detection for step one

Fig. 6. The robot moves into and leaves the elevator

The passive fire module detects the fire source in the second floor, and displays the fire symbol in the right side of Fig. 5(a). The image system recognizes the fire source using the Otsu method, and decides the fire event to be true, and transmits the fire signal to the supervised computer. The user interface displays the fire symbol, too. The mobile robot detects the fire source in the second floor. The supervised computer decides the fire event to be true using weighted average method according to the signals of the passive fire module, the image system and the mobile robot, and orders command to the other mobile robot that is moving in the first floor. The detection processing is step one. We can see the fire symbol is plotted in the robot (No. 2). The robot (No. 1) moves in the first floor, and has not searched the fire source. The user interface displays no fire symbol to be shown in Fig. 5(b).

(a)

(b)

Fig. 7. The experimental result of fire detection for step two

The mobile robot of the first floor receives the command from the supervised computer, and moves to the front side of the elevator using the IR distance module autonomously. The movement scenarios are shown in Fig. 5(c). The assigned robot controls the elevator via wireless RF interface, and moves into the elevator going up to the second floor. The elevator moves to the assigned floor to stop, and opens the doors to trip the mobile robot leaving the elevator via wireless RF interface. The assigned mobile robot leaves the elevator, and turns right 90^0 moving to the fire source. The movement scenarios are shown in Fig. 6(c).

The assigned mobile robot moves approach to the location of the robot (*No.2*), and detects the fire event using flame sensor, and transmits the event signal to the supervised computer to be shown in Fig. 7(a). The user interface displays fire symbol for the two robots. The supervised computer receives the event signal to give the final decision. The detection result presents the fire event to be true according the logical filter method. The detection processing is step two to be shown in Fig. 7(b). .

V. CONCLUSION

We have presented a multi-level based intelligent security system to be applied in intelligent home. The controller of the detection modules is HOLTEK microchip. We use multiple fusion algorithms to enhance the accuracy for the fire detection. Mobile robots, image system and passive detection modules are integrated in the security system, and can transmit real-time event signals to the supervised computer. The supervised computer decides the fire event to be true using fusion algorithm, and orders command to the other mobile robots. The assigned mobile robots can move to the position of the fire event doing double check. The experimental results are very nice to decide the fire event occurrence. In the future, we want to integrate more and more detection modules, and cooperate with the multi-robot system, and use multi-sensor fusion algorithms to enhance the accuracy. The intelligent security can be applied in many fields, such as hospital, transportation, building and factory. We can extend the results to be applied in gas leakage detection and intruder detection, too.

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