

# Designing of Multi-Agent Rescue Robot: Development and basic Experiments of Master-Slave Type Rescue Robots

J. Lin, T.C. Kuo, C.-Y. Gau, K.C. Liu<sup>2</sup>, Y.J. Huang, J.D. Yu, Y.W. Lin

**Abstract**—A multi-agent type robot for disaster response in calamity scene is proposed in this paper. The proposed grouped rescue robots can perform cooperative reconnaissance and surveillance to achieve a given rescue mission. The multi-agent rescue of dual set robot consists of one master set and three slave units. The research for this rescue robot system is going to detect at harmful environment where human is unreachable, such as the building is infected with virus or the factory has hazardous liquid in effluent. As a dual set robot, with Bluetooth and communication network, the master set can connect with slave units and send information back to computer by wireless and monitor. Therefore, rescuer can be informed the real-time information in a calamity area. Furthermore, each slave robot is able to obstacle avoidance by ultrasonic sensors, and encodes distance and location by compass. The master robot can integrate every devices information to increase the efficiency of prospected and research unknown area.

**Keywords**—Designing of Multi-Agent Rescue Robot, Development and basic Experiments of Master-Slave Type Rescue Robots

## I. INTRODUCTION

DISASTER response is always a race against time, to move as fast as possible to reach all potential survivors and yet more slowly enough to avoid creating additional collapses, damage, or risk to rescuers and victims. Rescue robots serve as extensions of responders into a disaster, providing real-time video and other sensory data about the situation. Therefore, the principal motivation is to save lives; robots can assist in appointment this goal either by interacting directly with victims or structures or automating support activities [1]. In general, the robot divides into many different categories, such as manufactory product, family appliance, security keeping, and outer space detection, etc. Research for robot development history in the world, the creativity of new technology has broken imagination and represented human intelligence. For example, IRobot Company of United States produced vacuum cleaning robot [2], SONY developed the robotic pets, AIBO [3], Korea Institute of Science and Technology (KIST) created humanoid robot, MAHRU [4], HONDA Company has humanoid robot, ASIMO [5], and the intelligence laboratory of Massachusetts Institute of Technology (MIT) design of a quadruped robot for social interaction, CoCo plan [6].

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At present, multi-robot systems has been developing nationwide. Researchers generally agree that multi-robot systems have several advantages over single-robot system [7]. For such case, “Master-Slave Type Planetary Rover”, which is indicated in [8], consists of master and slave unit. Recently, multi-agent robot system become popular research topics, which can be utilizing link communication by sensors [9], navigation of autonomous mobile [10], and neural-network-based path planning for a multi robot system with moving obstacles [11]. The most common motivations for developing multi-robot system solutions are that: the task complexity is too high for a single robot to accomplish; the task is inherently distributed; building several resource-bounded robots is much easier than having a single powerful robot; multiple robots can solve problems faster using parallelism. Hence, the issues that must be addressed in developing multi-robot solutions are dependent upon the task requirements and the sensory and effector capabilities of the available robots [12]. Moreover, rescue is a demanding application and it is reasonable to expect that new types of robots will evolve to meet the challenge. Rescue robots are needed to help quickly locate, assess, stabilize, and remove victims who cannot be easily reached. They typically do this by extending the rescuers’ ability to see and act [1]. Hence, numerous tentative designs for unmanned ground [13] and aerial vehicles [14] have been proposed. Moreover, literature [15] demonstrates the snake robots to the rescue. However, all the above studies only concentrate on the single robot design; none of these studies developed a multi-robot system for rescue purposes. Thus, this paper presents a multi-agent type rescue robot for disaster response in calamity scene. The plan for this rescue robot is going to detect at harmful environment where human is unreachable and low rescuer risk. The multi-agent rescue of dual set robot consists of one master type autonomous guided vehicle (AGV) and three slave type AGVs. As a dual set robot, with Bluetooth and communication network, the master set can connect with slave units and send information back to computer by wireless and monitor. Therefore, rescuer can be informed the real-time information in a calamity area. Furthermore, each slave robot is able to obstacle avoidance by ultrasonic sensors, and encodes distance and location by compass. The master robot can integrate every device’s information to increase the efficiency of research and increase the ability for saving people and rescue task.

## II. SYSTEM STRUCTURE

The structure of multi-agent rescue robot system is a kind of autonomous guided vehicle (AGV) type and shown as in Fig. 1. AGVs are capable of performing tasks without the intervention

of human operators. They should contain built-in machine intelligence and an onboard control system. Therefore, the master robot is carried a notebook computer (NB), and using Visual Basic (VB) software to design the human-machine interface. By using Bluetooth, the master robot and slave robots can send data to communicate each others, and operate the rescue task.

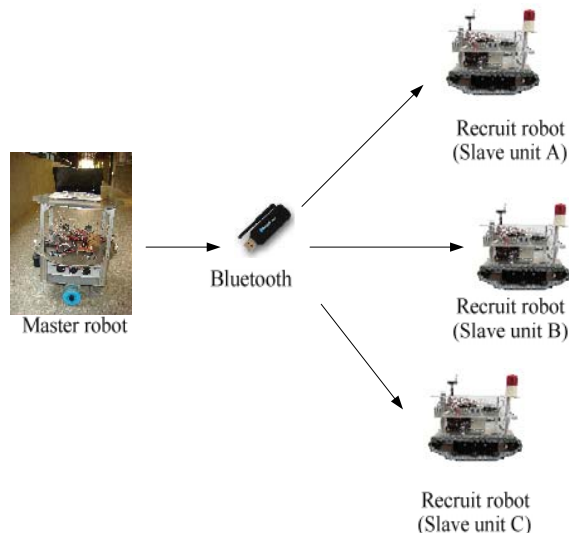


Fig. 1 The structure of multi-agent rescue robot system

### 2.1 Structure of master set

The structure of master set is demonstrated in Fig. 2. The process of operating is through Field Programmable Gate Array (FPGA) to integrate DC motor, ultrasonic sensors, compass and Bluetooth. The FPGA will connect to computer by RS232. The master set is action by using three omi-direction wheels and DC motor to obtain optimum position as fast as possible.

The hardware component of master set consists of three floors. The lowest floor is setting up one infrared drivers, three DC motors, and battery. The middle floor has FPGA controller, eight ultrasonic sensors, Bluetooth, and circuit regulator. The upper floor contains of wireless camera and NB.

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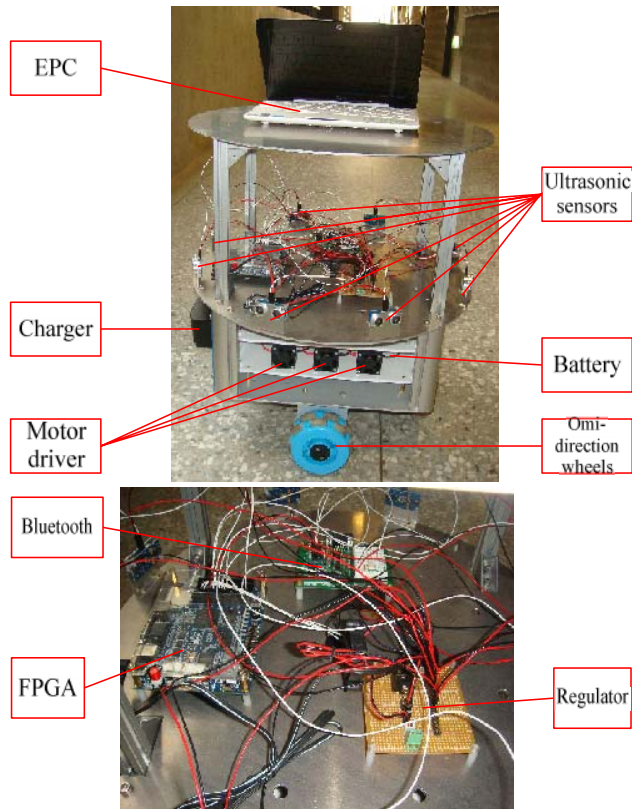


Fig. 2 The hardware component of master robot

### 2.2 Structure of slave units

The structure of slave unit is indicated in Fig. 3. By using FPGA, the slave unit integrates sensors, DC motor, and carries rescue equipments. For successful sending information back to master set at a calamity scene, the slave robot is using Bluetooth to communicate, human activity detection sensors to find victims. In order to reach the target, the slave robot is using track instead of wheels, and implement intelligent control law to obstacle avoidance.

The component of the slave unit also owns three floors. The lowest floor is loading of two DC motors, driver and batteries. The middle floor has FPGA controller, eight ultrasonic sensors, compass, accelerometer, and circuit regulator. The upper floor contains of human detection sensors, wireless camera and light alarm.

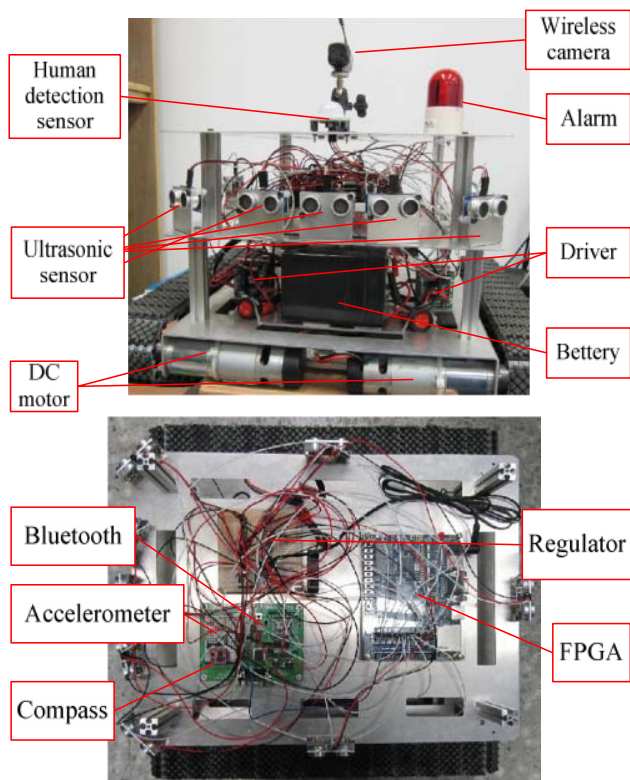


Fig. 3 The hardware structure of slave robot

### III. SYSTEM DESIGNS

#### 3.1 DC motor

The FPGA's output is digital signal that has to using pulse width modulation (PWM) to adjust pulse and change duty cycle to receive an equalized voltage output. There is a counter to produce every signal data for PWM and connect with comparator as a receiver. Further, the output voltage of FPGA is 3.3V that it is not enough to operate DC motor. Therefore, it needs a DC motor driver to compensate the output voltage.

#### 3.2 Ultrasonic sensors

The ultrasonic sensors which provided by Parallax company is designed as detect device to count time from emitting to receive signal back. There are four detection moulds of ultrasonic sensors which can detect obstacle into positive data at least 2 cm far.

#### 3.3 Infrared sensor for human activity sensing

The methodology of human activity detection is using principle of energy level changing. This sensor is contained of mertriglycinesulfate (TGG) and lead zirconate titanate (PZT) as piezoelectric material. The voltage of power is about 3~15VDC and temperate coefficient from  $-10^{\circ}C \sim +50^{\circ}C$ . The output signal is extreme small that is only few mV and can receive any hot energy inferred (which is include human).

In reality testing, the human activity detection sensors can receive the difference of output voltage. While there are a people or hot product passing the sensors, one of detection sets will be excited and progress high voltage. While the second

detection set has been excited in follow, the voltage will become lower.

#### 3.4 Compass

The compass is using the magnetic field (the North Pole) to examine direction. The principle of compass is measured change of angle when object changes the direction. The compass consists of a couple vertical coils and follows electromagnetic induction to find the direction, which is measured vector from voltage in the two coils. However, the compass has placed on the robot, which is made by steel. The accurate of compass will affect by magnetic field from earth and robot itself. Further, if may has affect by wire pole or steel building when the robot pass through.

#### 3.5 Process of obstacle avoidance

In order to obstacle avoidance, the robot needs to use ultrasonic sensor to receive area information and then set up direction function. Thus, the robot has to detect whether there is block in the route. According to strong or low signal received by, the robot can count the comparative distance between robot and block. To combine all of data from sensor, the robot can calculate the optimum route and moving speed.

The obstacle avoidance for this paper is using the ultrasonic sensors to detect the block that it adapts reflecting split type ultrasonic sensors which can detect from 2cm to 3m. The information data from sensors has through FPGA to determine and analyze. By calculating the time to receive data back, the distance between object and sensor is measurable.

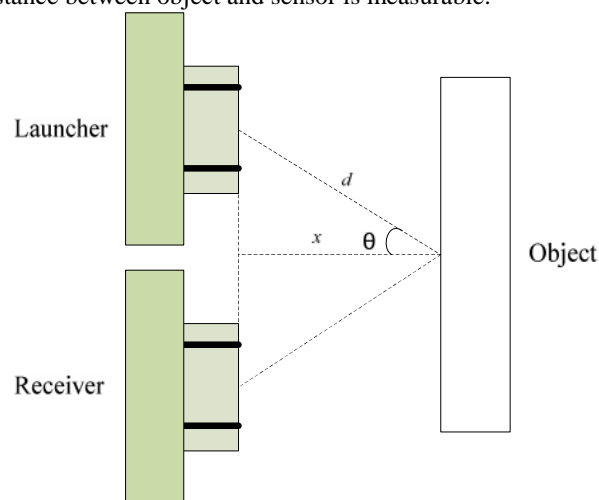


Fig. 4 The principle of ultrasonic sensors

By calculating the time to receive data back, the distance between object and sensor is measurable, which is shown as Fig. 4. The equation will be

$$x (\text{Distance}) = v (\text{rate}) \times t (\text{time}). \quad (1)$$

Assume that operation temperature is  $20^{\circ}C$ , the rate of ultrasonic wave in air is 343m/s and the sound speed ( $c$ ) is changed by temperature ( $T$ ), then

$$c = 331.5 + 0.6 \times T, \quad (2)$$

where  $T$  is operation temperature,  $c$  is sound speed, and

$$x = \frac{c \times t \times \cos \theta}{2} \quad (3)$$

$$d = c \times \frac{t}{2} \quad (4)$$

where

$t$  is the time to receive single after sensors sending out,  
 $\theta$  is the angle of incidence from wave,  
 $x$  is the shortest distance of reflection from sensors,  
 $d$  is the half of realistic transfer distance.

The primeval control system is set up for the robot to go straight and then detecting the environment back to controller. In there is on block in front, it will count the optimum route and order slave robots to move, and then scanning the area again. The setting function for sensor is shown as Fig. 5, which is using eight ultrasonic sensors. The slaves units carry with sensors into number S0 ~ S7 and arrowheads are direction that surround the slave robot into angle of (0, 45, 60, 90, 120, 135, 180, and 270). The wave signal can be calculated for distance. Figure 6 demonstrated the flow chart of the logical function. While start moving, it will scan if there is a block or not. If there is a block in front, it will calculate that go right side is shorter or go left side (finding the two smallest values in S1 and S6, and S3 and S7). Then the controller will send data to DC motor to process real-time action for obstacle avoidance. Whereas there is back to a go straight order which means there is no block in front, the obstacle avoidance function will go back the function cycle.

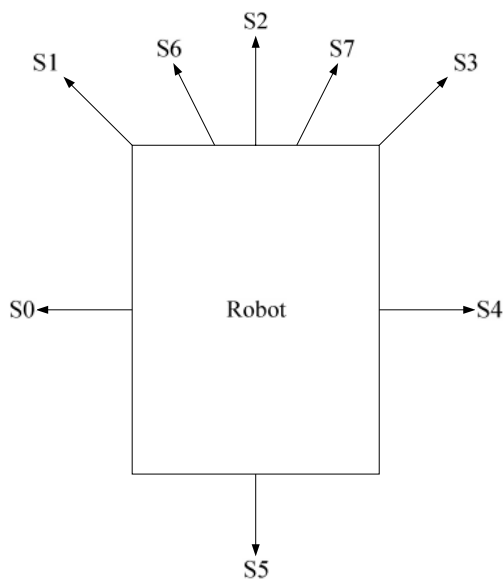


Fig. 5 The setup of sensors

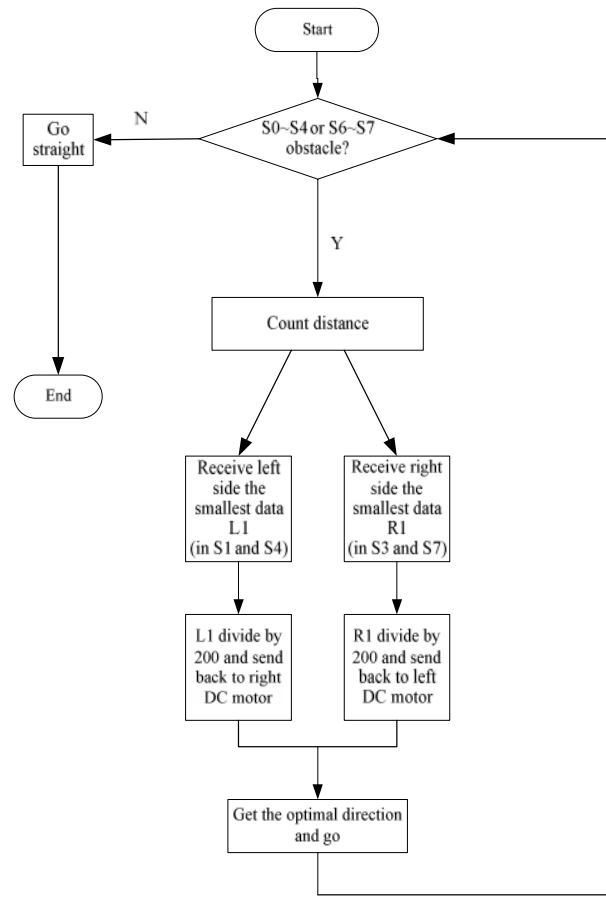


Fig. 6 Flow chart of logical function

### 3.6 VB human-machine interface

The VB human-machine interface has been established (Fig. 7). According to operate many robots in the same time, the user can connect and command to robots by NB. However, with human nature, the user may make a wrong command to robot. These robots have loaded sensors for obstacle avoidance ability due to wrong direction order. Therefore, for complete a rescue task; there is remote control for controller, obstacle avoidance for robot itself and automatically operation.

As the Fig. 8, the top left corner of interface is showing the block near by the robot into an arc sign. If there is detected a victim, the function will switch into remote control system for operating rescue process.

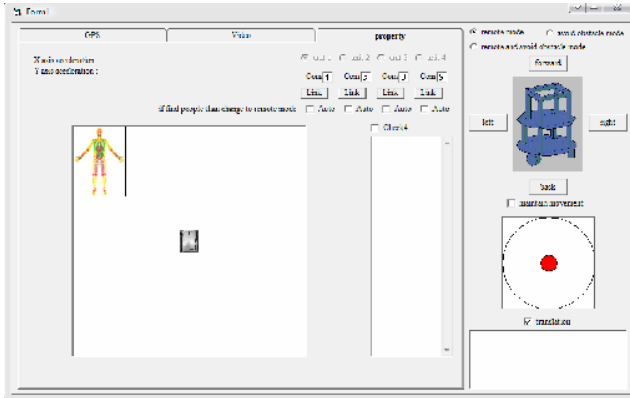


Fig. 7 VB human-machine interface

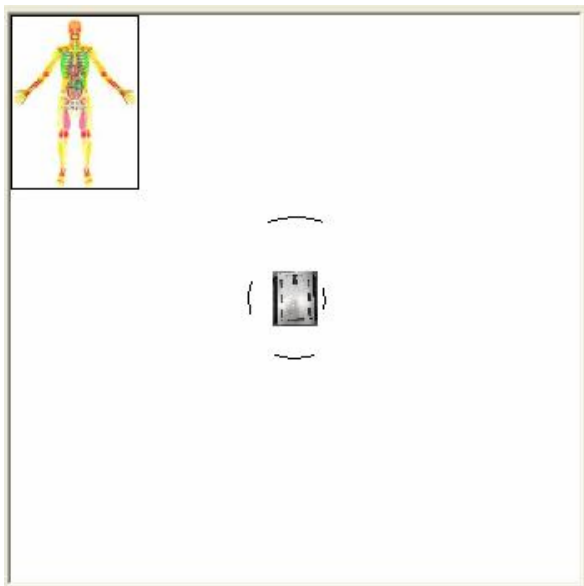


Fig. 8 Obstacle interface

#### IV. RESULTS AND DISCUSSIONS

##### 4.1 The simulation and environment of experiment

For simulation program, when there is a block in front of robot, the robot will collect the smallest distance from each side of right and left (Fig. 9), where  $D_L = 2d$ ,  $D_R = d$ . While the slave robots are continued in a straight direction, the speeds of track on right and left side will be considered as  $V$  ( $V_L = V_R = V$ ). Despite the fact that there is a block in front, the obstacle avoidance function will send  $D_L$  and  $D_R$  data to right and left DC motors, and control the speed. The distance data from left side block sends to right DC motor and the right distance data sends to left DC motor, where  $V_L = V'$ ,  $V_R = 2V'$ . Therefore, the slave robots are able to avoid obstacle.

The scenario simulation is setting at a  $7m \times 6m$  limited room (Fig. 10). The slave robots can operate detection automatically and avoid obstacle. Whereas there is scanning a body around, the robot will switch into remote system for rescuer to control.

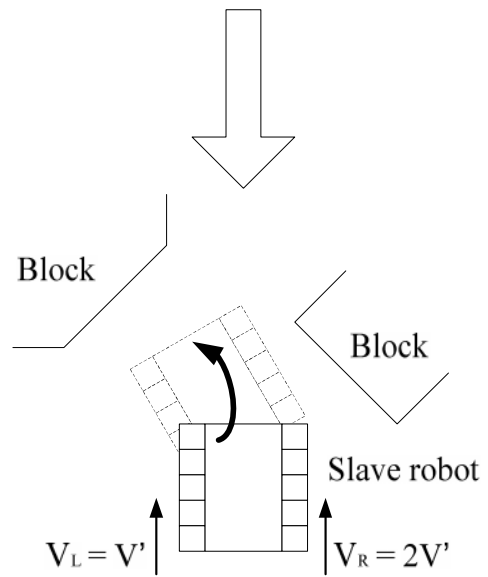
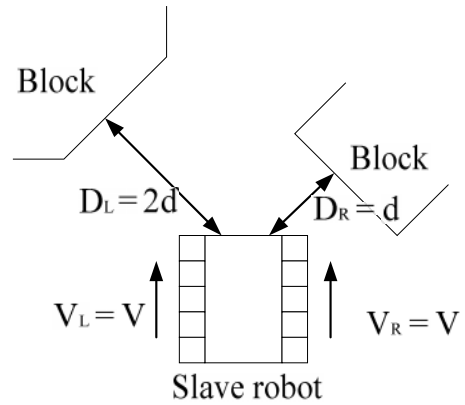


Fig. 9 Obstacle avoidance

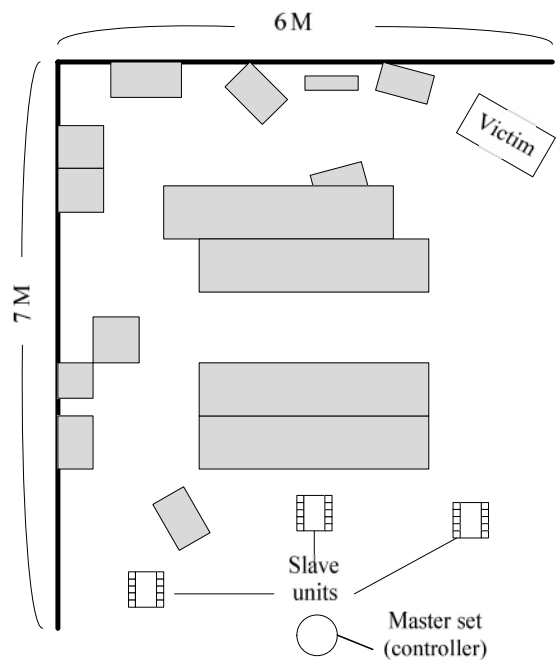


Fig. 10 Simulation environment

#### 4.2 Result of experiment

Figure 11 demonstrates the slave robots operate successfully for obstacle avoidance. As the figure, the robot can operate automatically and let user catch the realistic environment. While finding a victim, the robot will switch function into remote control for rescue. Moreover, the left bottom corner of Fig. 11 indicated as the real-time video come from the slave robot monitoring the calamity area by using wireless camera.



Fig. 11 The realistic operation

Moreover, the experiment also demonstrates a successful realistic operation for the multi-agent robot with three slave robots for detection and obstacle avoidance (Fig. 12). Each slave robot owns the individual intelligent capability such as search, feeding real-time video, and obstacle avoidance. In addition, the slave robots can also provide real-time video and other sensory data to the master robot. The master robot can play the integration of the information from the slave robots and then constructs the environmental map for the rescue purposes.





Fig. 12 The test of multi-agent robot

## V. CONCLUSIONS

Rescue robots are making the transition from an attractive idea to an integral part of emergency response. The proposed multi-agent robot was successfully developed which can adapt in to calamity scene. This robot system has one master set and three slave units. This multi-agent robot is loaded Bluetooth for communication, ultrasonic sensors for obstacle avoidance. The slave robots carry with compass to calculate distance and position. Master robot can receive and integrate these data from sub devices to make map. Moreover, while the environment can not be reached by human, the multi-agent rescue robot can instead of people to detect the calamity area and send back information to rescuer in order. Realistic operation for the proposed multi-agent robot system has successfully verified in the real-time experiment. Consequently, the advantages of the proposed grouped rescue robots can perform the high efficiency for the rescue tasks.

## REFERENCES

- [1] R.R. Murphy, S. Tadokoro, D. Nardi, A. Jacoff, P. Fiorini, H. Choset, A.M. Erkmen, "Search and rescue robotics," B. Siciliano and O. Khatib (eds.), *Springer Handbook of Robotics*, Springer-Verlag, New York, 2008, pp. 1151-1173.
- [2] <http://www.irobot.com>
- [3] <http://www.jp.aibo.com>
- [4] [http://humanoid.kist.re.kr/eng/mahruahra/info\\_01.php](http://humanoid.kist.re.kr/eng/mahruahra/info_01.php)
- [5] <http://www.honda-taiwan.com.tw/asimo>
- [6] <http://www.ai.mit.edu/projects/humanoid-robotics-group/coco/the-robot.html>
- [7] T. Arai, E. Pagello, L.E. Parker, "Advances in multi-robot systems," *IEEE Trans. Robot. Autom.*, vol. 18, no. 5, pp. 655-661, 2002.
- [8] A. Kawakami, A. Torii, and S. Hirose, "Design of SMC rover: development and basic experiments of arm equipped single wheel rover", *Proceedings of IEEE/RSJ IROS*, 2001.
- [9] J. Rogge and D. Aeyels, "Sensor coverage with a multi-robot system," *IEEE 22nd International Symposium on Intelligent Control*, pp. 71-76, 2007.
- [10] A. Cezayirli and F. Kerestecioglu, "Navigation of autonomous mobile robots in connected groups," *International Symposium on Communications, Control and Signal Processing*, pp. 162-167, 2008.
- [11] H. Li, S. X. Yang, and M. L. Seto, "Neural-network-based path planning for a multirobot system with moving obstacles," *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 39, no. 4, pp. 410-419, 2009.
- [12] L.E. Parker, "Multiple mobile robot systems," B. Siciliano and O. Khatib (eds.), *Springer Handbook of Robotics*, Springer-Verlag, New York, 2008, pp. 921-941.
- [13] R. Murphy, S. Stover, H. Choset, *Lessons learned on the uses of unmanned vehicles from the 2004 Florida hurricane season*. In: AUVSI Unmanned Systems North America, Baltimore (Association for Unmanned Vehicle Systems International, Arlington 2005)
- [14] K.W. Sevick, W.E. Green, P.Y. Oh, "Exploring search-and-rescue in near-earth environments for aerial robots," *IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, pp. 693-698, 2005.
- [15] I. Erkmen, A. M. Erkmen, F. Matsuno, R. Chatterjee, and T. Kamegawa, "Snake robots to the rescue," *IEEE Robotics & Automation Magazine*, vol. 9, no. 3, pp. 17-25, 2002.