An Experimental Multi-Agent Robot System for Operating in Hazardous Environments

Y. J. Huang, J. D. Yu, B. W. Hong, C. H. Tai, and T. C. Kuo

***Abstract*—In this paper, a multi-agent robot system is presented. The system consists of four robots. The developed robots are able to automatically enter and patrol a harmful environment, such as the building infected with virus or the factory with leaking hazardous gas. Further, every robot is able to perform obstacle avoidance and search for the victims. Several operation modes are designed: remote control, obstacle avoidance, automatic searching, and so on.**

***Keywords*—**autonomous robot, field programmable gate array, obstacle avoidance, ultrasonic sensor, wireless communication.

I. Introduction

FOR a long time, many researchers have been developing omnipotent robots which can substitute human or work everything that human cannot do. For example, a variety of robots have been built, such as the vacuum cleaning robot [1], the robotic pets AIBO [2], the humanoid robot MAHRU [3], the humanoid robot ASIMO [4], the biomimetic robotic fish [5], and so on.

In recent years, the multi-agent robot system has become a popular research topic. This topic involves communication with sensors, autonomous navigation, and path planning [6-8]. For the rescue robots, the underwater rescue robot and robots for the mineral explored in the sea floor are also developed [9-11]. Up to present, applications of service robots can be found widely recently. However, consider the flexibility and the prospect of team work, the application of the multi-agent robot system is comparatively worth to be explored.

This paper presents a multi-agent robot system for detecting and rescuing human victims in a harmful environment. The proposed system consists of one main set and three sub devices. The main set robot can communicate with sub device robots through wireless network. Every robot is able to perform obstacle avoidance. The main set robot collects all information sending from each sub device robot and efficiently calculates a way to complete the rescue task.

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II. Main Result

The hardware of the multi-agent rescue robot system is shown in Fig. 1. The main set robot carries a notebook. Visual Basic language is used to design the human-machine interface. By using Bluetooth technology, the main set robot and sub device robots can communicate with one another. They incorporate with each other to operate the rescue task.

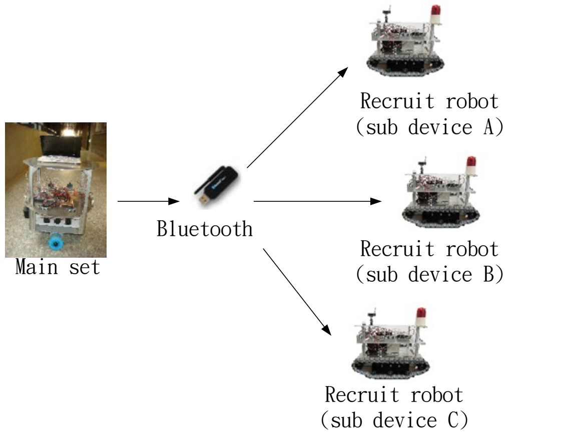

Fig. 1. The structure of multi-agent rescue robot.

A. Structure of Main Set Robot

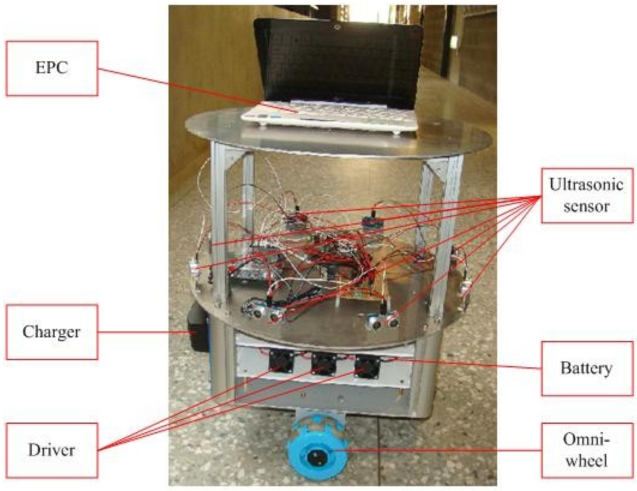

Fig. 2. The structure of the main set robot.

The main content of the main set robot is shown in Fig. 2. An FPGA board integrates DC motors, ultrasonic sensors, compass and Bluetooth device. The FPGA is connected to a notebook through RS232. The main set robot is driven by three omni-directional wheels and DC motors such that the turning of the robot could be accurate and as fast as possible.

There are three stages in the main set robot. The lowest stage is set up with one infrared driver, three DC motors and omni-wheels, and batteries. The middle stage has an FPGA controller, eight ultrasonic sensors, a Bluetooth device, and a PC board. On the upper stage are the wireless camera and notebook.

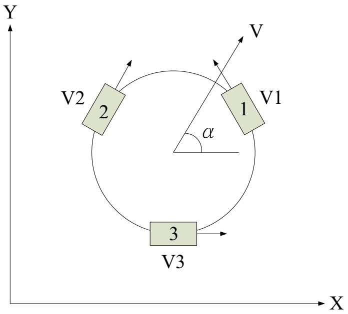

Fig. 3. Module of omni-wheel robot

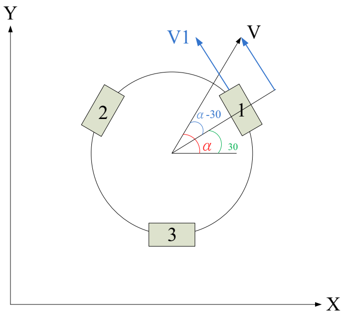

Fig. 4. Derived graph of No.1 wheel

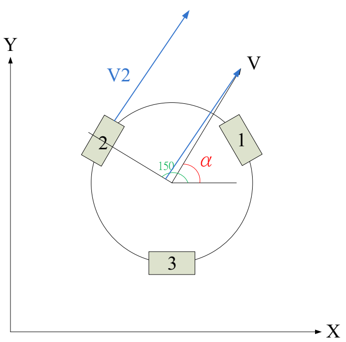

Fig. 5. Derived graph of No.2 wheel

The omni-wheels can move along any direction. As shown in Fig. 3, V is speed and direction of the robot, V1, V2 and V3 are individual speed of No. 1 wheel, No. 2 wheel and No. 3 wheel. The central content is how to design speed and direction of the unit wheel and how to control all the three wheels of speed and direction. In order to derive the full equations of omni-directional platform, the wheels will be separated to discuss, which are shown in Fig. 4, Fig. 5, and Fig. 6.

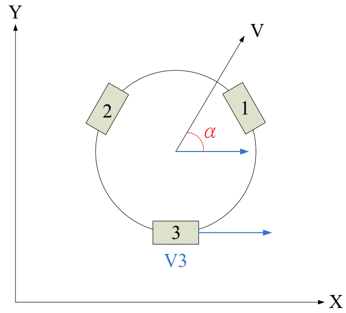

Fig. 6. Derived graph of No.3 wheel

The motion equations of the omni-wheels can be derived as follows.

No.1 wheel: $V1 = V \times \sin(\alpha - 30)$

No.2 wheel: $V2 = V \times \sin(\alpha - 150)$

No.3 wheel: $V3 = V \times \cos(\alpha)$

B. *Structure of Sub Device Robot*

The structure of the sub device robot is shown in Fig. 3. By using FPGA, the sub device robot integrates sensors, DC motors, and carries rescue-functional equipments. For sending information back to main set robot in a calamity scene, the Bluetooth technology is used for communication. Distance sensor and human sensor are used to find victims. In order to reach the victims, fuzzy control algorithm and ultrasonic sensors are used for obstacle avoidance and self-navigation.

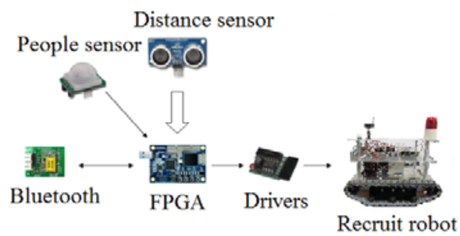

Fig. 7. The structure system of sub device robot.

The hardware of the sub device robot is shown in Fig. 8. There are three stages of the hardware. The lowest stage carries two DC motors, one driver and batteries. The middle stage has an FPGA controller, eight ultrasonic sensors, compass, accelerometer, and a PC board. The upper stage carries human sensors, wireless camera, and alarm.

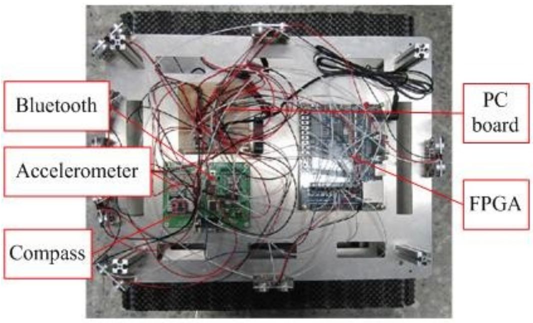

Fig. 8. The hardware of sub device robot.

C. *Process of Obstacle Avoidance*

For the obstacle avoidance, the robot system needs to utilize all the information obtained from ultrasonic sensors to explore the environment. In other words, the robots have to detect whether there is any obstacle in the route. In our applications, our sensors can detect a distance shorter than 3m. The process of receiving information data from sensors and analysis are fulfilled with an FPGA board.

The common command for the robots is to go straight. If there is one obstacle in front, the controller will determine the optimal route and give order to the robots to avoid the obstacle, and then scan the area again. The setting of sensors is shown in Fig. 9. Eight ultrasonic sensors are used. The computation procedure is described as follows. At first, the robot scans to investigate if there is an obstacle or not. If there is an obstacle in front, then calculate whether going right side is shorter or going left side is shorter(finding the two smallest values in S1 and S6, and S3 and S7). Then the controller will send necessary data to DC motors to process real-time action for obstacle avoidance. After the obstacle avoidance function is done, the robot goes back to the go-straight function.

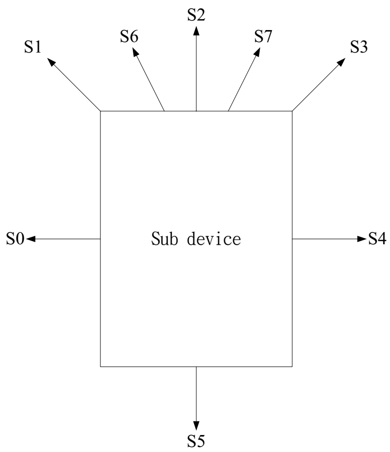

Fig. 9. The setting of the ultrasonic sensors.

D. *Human-Machine Interface*

The human-machine interface is set up for the user to control and monitor the robots as show in Fig. 10. Simultaneously operating several robots is not a simple task. Here we connect and command all the robots with a notebook. In case the operator gives a wrong movement command to any robot, those robots still can perform obstacle avoidance with first priority. For a complete rescue task, we set up several solutions for different modes, including remote control, obstacle avoidance, automatic searching, and so on.

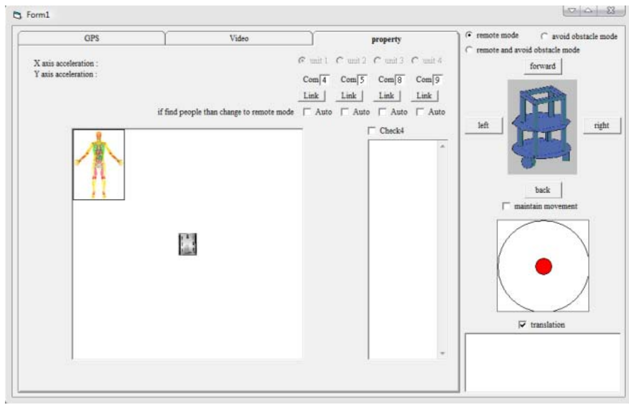

Fig. 10. Human-machine interface.

III. Experiment Results

As seen in Fig. 11, the robot will detect which is the smaller distance on the right or left side. In Fig. 11, $D_L = 2d$ and $D_R = d$. Therefore, the robot turns to left. When the robot goes straight, the speed of track on right and left side will be considered as V (V_L=V_R=V). In case there is an obstacle right in front, the obstacle avoidance function enables the D_L and D_R data to drive the right and left DC motors. Suitable control is calculated for obtaining the suitable speed. In short, the distance data from left side obstacle is sent to the right DC motor; and the right distance data is sent to the left DC motor. In Fig. 11, V_L=V' and V_R=2V'. Therefore, the robot rotates left-hand side and is able to avoid hitting obstacles.

The experiment is carried out in a $7\text{m} \times 6\text{m}$ room. The sub device robot can avoid obstacles and find its own way to search for human victims. When a victim is found, the remote control mode is activated. The outside operator manipulates the robots and rescues the victim subsequently.

The successful operation of the multi-agent robot system is shown in Fig. 12. Three sub device robots go out for searching the victims and perform the obstacle avoidance at the same time. They can also climb small obstacles less than 8 cm in height.

IV. Conclusions

A multi-agent robot system is developed and presented in this paper. The primary purpose of this work was the application in a calamity scene. This work is mainly supported by the Council of Labor Affairs, Executive Yuan, Taiwan. The goal is to develop a possible rescue method for saving lives in a hazardous environment, such as infected factories with poison gas. One main set and three sub devices are proposed. Bluetooth technology is used for communication. Obstacle avoidance technique is developed. The main set will be further designed to generate a map of the geographic environment. We hope that when the environment is dangerous for human to enter, the proposed multi-agent robot system can explore the calamity area and send back the environment information to rescue victims.

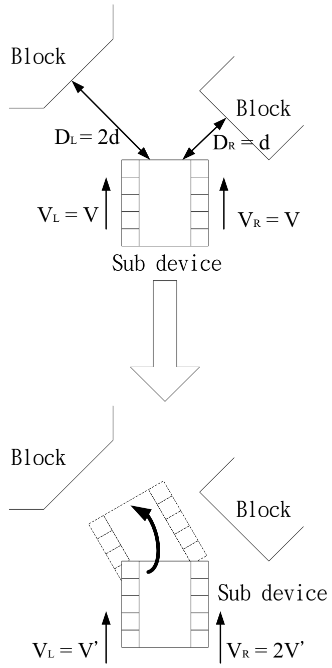

Fig. 8. Description of obstacle avoidance.

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(a)

(b)

(c)

Fig. 12. The operation of multi-agent robots.