'92 KACC 1992. 10. 19~21

A MULTIPLE AUTONOMOUS ROBOTS SYSTEM

— HARDWARE AND COMMUNICATION

W. A. Johari H.*, M. Nohira**, Y. Yamauchi***, S. Ishikawa*, K. Kato*

*Department of Electrical, Electronic and Computer Engineering, Kyushu Institute of Technology, Tobata, Kitakyushu 804 JAPAN
** Sumitomo Metals Co. Ltd., Kokura-kita, Kitakyushu 802 JAPAN
***Yaskawa Information Systems Co. Ltd., Yahata-nishi, Kitakyushu 806 JAPAN

ABSTRACT

This paper describes a hardware structure and a communication system of a multiple autonomous robots system. Many studies have been devoted to the development of a single autonomous robot. It is, however, also necessary to investigate decentralized multiple autonomous robots system in order to make wider use of such robots. We have been studying a multiple autonomous robots system employing two mobile robots. In this paper, problems are overviewed on the developed multiple autonomous robots system from the viewpoint of hardware and communication, and an improved system is presented, which employs a new control strategy of a mobile robot and realizes reliable data communication between host computers.

1. INTRODUCTION

The advance of computer technology causes the miniaturization of various existent systems and realization of high speed operation, and it leads robotic technology into a new era. Recent studies on an autonomous robot have been going prosperously. Researchers in this field are mostly involved in improving the functions of a single autonomous robot and realizing its new applications[1, 2]. A single robot, however, may have limitation in its possible behaviours. To overcome this limitation, the study on cooperative work by multiple robots needs to be done[3,4]. We have been investigating a decentralized autonomous robots system which is another advanced research in robotics.

The development of a multiple autonomous mobile robots system has three main stages prior to its application to cooperative work;

(1) making robots equipped with equivalent functions,
(2) developing their control systems,
(3) developing mutual communication systems among the robots.

So far two autonomous mobile robots have been developed, and a range and directional detection system has been deviced as well as a communication system. But this robots system has the following problems to be improved;

(1) movement of a robot and communication between host computers cannot be done simultaneously,
(2) simultaneous movement of the robot itself and the mounted TV camera is not possible,
(3) the control circuit of a robot is large,
(4) robot's control process is slow,
(5) unable to expand the functions, since its memory capacity is small,
(6) data collision may occur when communicating between host computers.

In order to make an improvement on the existent autonomous mobile robots system, a mobile robot equipped with a new control circuit and a new communication system has been developed. In this paper, a hardware and a communication system of the improved autonomous mobile robots system is presented.

2. THE SYSTEM STRUCTURE

A realized autonomous robots system has two mobile robots and their host computers. Communication between the host computer and the robot goes through a parallel interface, and mutual communication among robots takes place by a serial interface. By this communication system, the developed robot not only controls itself, but also makes cooperative work with other robots.

The robot itself is equipped with a TV camera, and the images acquired are fed into the computer to extract the information necessary for its next action. For its movement, it has four stepping motors; two for wheels and two for the camera movement. To control the movement and the communication, the robot has its own CPU circuit, communication circuit, and a driving circuit within its aluminium body. **Figure 1** shows an overview of the developed autonomous robots system. The present robots are shown in **Figure 2a**, and the newly developed robot is shown in Figure 2b.

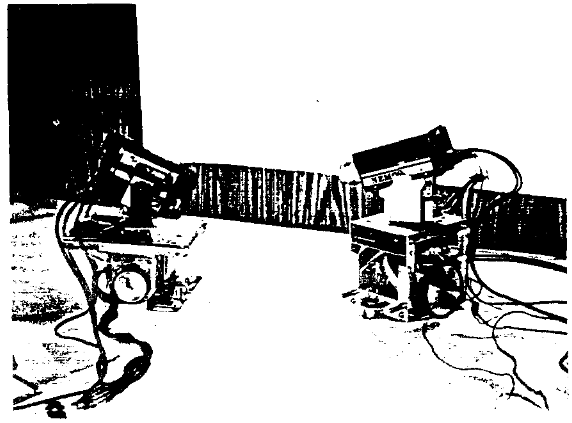

Figure 2a. Appearance of the present robots

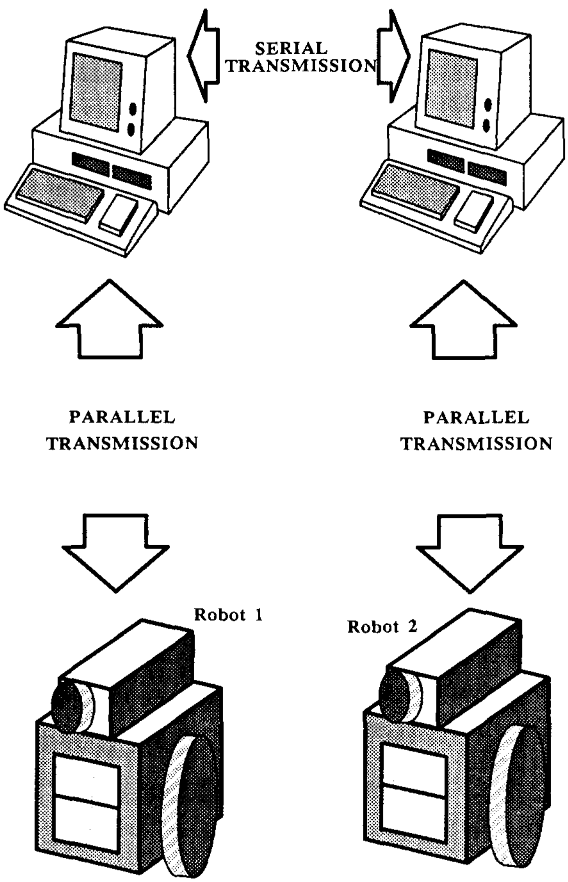

Figure 1. Overview of the developed autonomous robots system

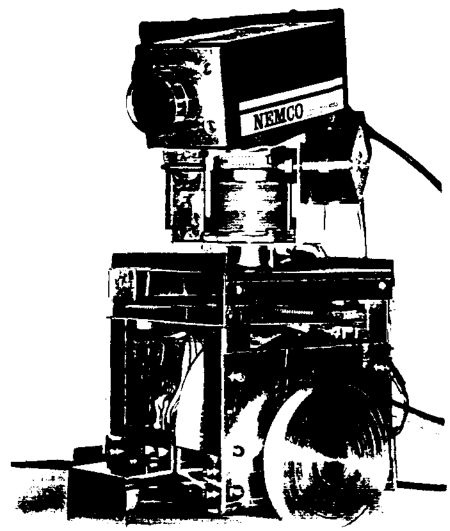

Figure 2b. A developed robot

3. THE HARDWARE STRUCTURE

Figure 3 shows the hardware structure of the developed autonomous mobile robot. It is composed of three parts: a CPU circuit, a communication circuit, and a driving circuit. Employing communication interfaces, the transmission of information goes through these circuits.

Each movement of the robot and its communication controls go through the CPU with its memory structure composed of 64KB of programmable ROM and 64KB of static RAM.

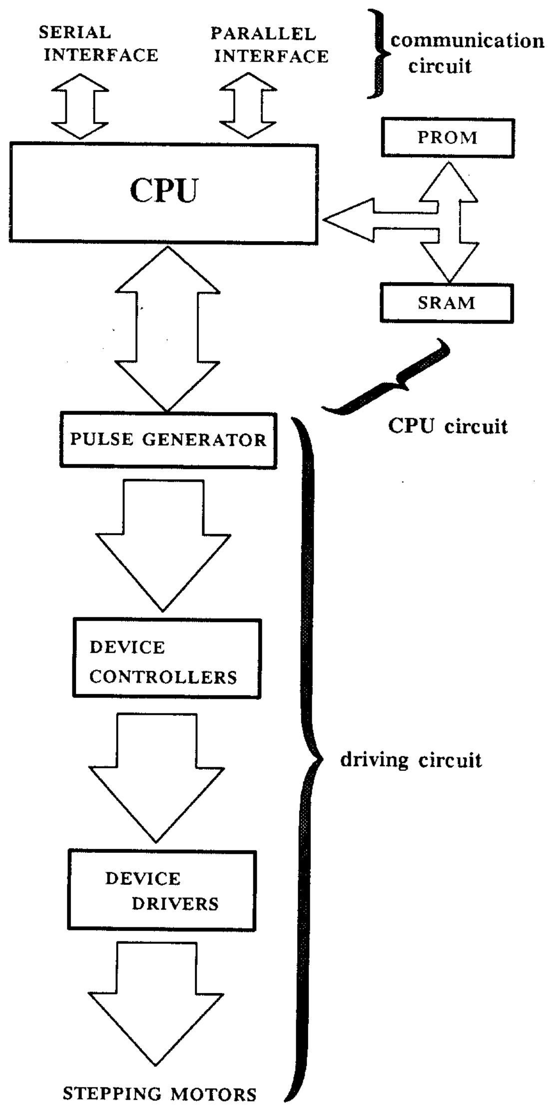

Figure 3. Hardware structure of the robot

The communication between the robot and its host computer goes through the parallel interface within its communication circuit. Using this parallel interface communication, the communication controller makes the host computer a controller, a listener and a talker, and the robot also becomes a talker and a listener.

In the driving circuit, stepping motors are used. These motors can be controlled by feeding them with several different phase of pulses. Since the amount of movement for each pulse is known, location of a robot can be easily calculated. Since a pulse generator can provide a few different pulses at a time to the driver and to the controller, the movement of wheels and the TV camera can be done simultaneously. As the result of having used this control circuit for driving the stepping motors, a simple circuit has been realized as a whole with respect to the mobile robot.

4. FLOW OF CONTROLS AND INFORMATION

Figure 4 shows the flow of information and controls related to the hardware of the system. The image information from a TV camera mounted on each robot goes through the image input board that host computer is equipped with. The host computer performs the image processing and the results are employed in determining robot's actions.

The control signals between the host computer and the robot goes through a parallel interface. It is used to transmit the movement control of the stepping motors, i.e, the information transmitted contains the direction of rotation and the number of pulses for the stepping motors. Conversely, in the transmission from the robot to the host computer, confirmation of the command that has been sent to the robot from the host computer is returned.

The information on a robot's location is sent to another host computer through a serial interface when it is requested. The serial interface is also used to exchange movement requests.

Data transmission between each host computer and a robot is performed by hand shaking[5,6]. Four bytes are used for the transmission. The first one byte contains the command on the movement of a camera and a robot (see **Figure 5**), the next two bytes are used for counting pulses sent to the stepping motors, and the last one byte is used to transmit the sign of the beginning of movement to the host computer. In this sign, robot sends back the transmitted data to the host computer when it is in order and does not send anything when it is in disorder.

In the present system data transmission between a host computer and a robot is performed in serially, and only a single movement command can be sent. In the developed system, data transmission is performed in parallel, where numbers of movement commands can be sent at a time (see **Figure 6**). As a result, the robot movement can be done simultaneously.

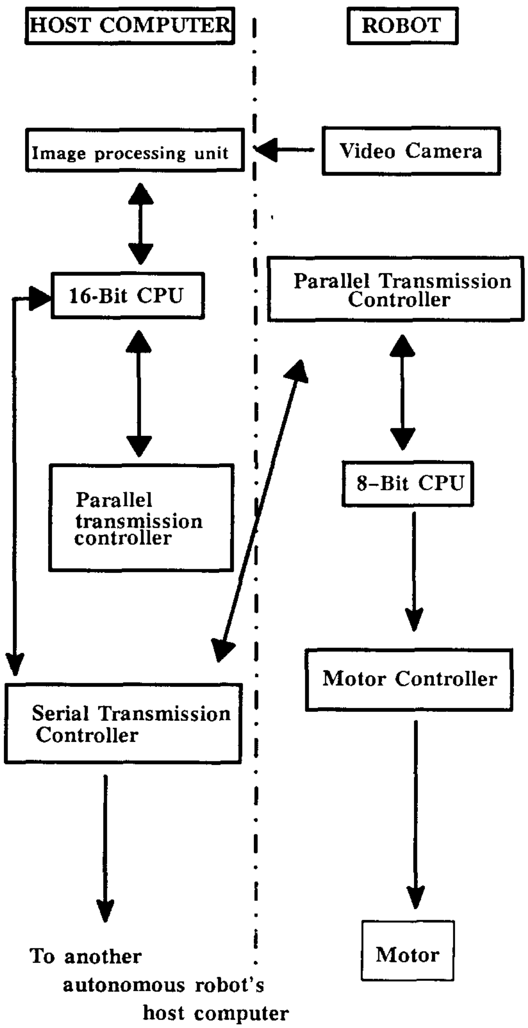

Figure 4. Information and controls related to the hardware

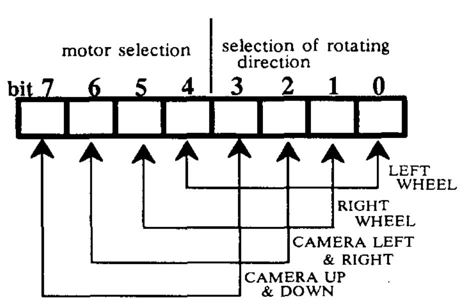

Figure 5. Commands transmitted to the robot

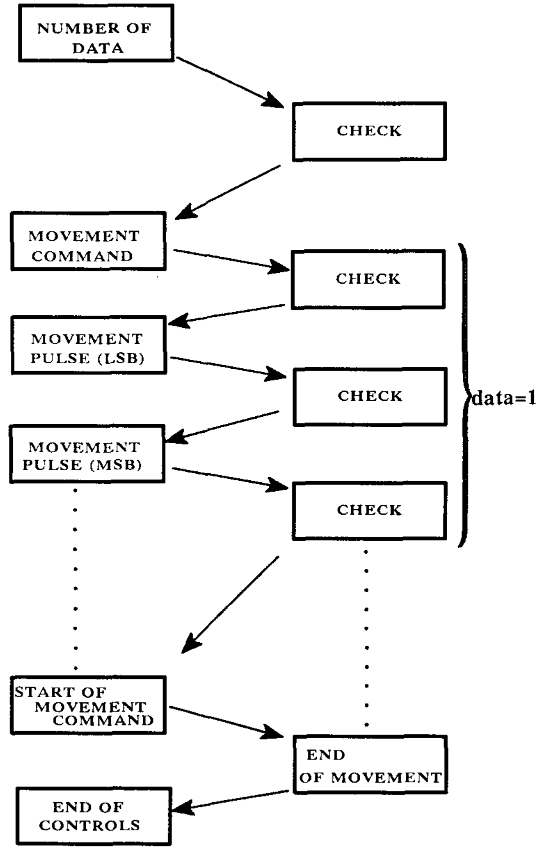

Figure 6. Transmission of movement information

5. INFORMATION EXCHANGE BETWEEN MOBILE ROBOTS

The information exchanged between the host computers is separated into three categories: movement commands to conduct another robot; information requests to get the positio of another robots; and the replies to the requests from another robots.

Movement commands

forward move : to make another robot move forward by a specified distance
backward move : to make another robot move backward by a specified distance
turn right : to make another robot turn right from the present location by a specified angle
turn left : to make another robot turn left from the present location by a specified angle

camera turn right : to make another robot's camera turn right by a specified angle
camera turn left : to make another robot's camera turn left by a specified angle

Information requests

camera's orientation request : to request the orientation of another robot's (receiver's) camera
body's orientation request : to request the orientation of receiver's body
location request : to request receiver's location on the requester's coordinate system
requester's camera orientation request : to request the orientation of requester's camera
requester's body orientation request : to request the orientation of requester's body
requester's location request : to request requester's location on the receiver's coordinate system

Transmission of information

information on the receiver's camera orientation : to transmit the camera orientation of the receiver
information on the receiver's body orientation : to transmit the body orientation of the receiver
information on the receiver's location : to transmit the location of the receiver on the requester's coordinate system
information on requester's camera orientation : to transmit the orientation of requester's camera in view of the receiver
information on requester's body orientation : to transmit the orientation of requester's body in view of the receiver
information on requester's location : to transmit the location of the requester in view of the receiver

6. COMMUNICATION SYSTEM

Mutual communication among the autonomous robots is performed based on the binary synchronous communication (BSC) system[5,6]. In this system, control characters are the elements of the basic structure of the system, and it controls the transmission of information block (see **Table 1**). **Figure 7** shows the binary synchronous communication system. When there are some data to transmit, ENQ is transmitted first by a sender to ask a receiver if it is ready for the data transmission. When the receiver is ready, ACK is returned, otherwise NACK is replied. When ACK is returned, the data is transmitted in a specified format.

Table 1. Transmitted characters

ACK : *Acknowledge*
BCS : *Block check sequence*
ETB : *End of text block*
ENQ : *Enquiry*
EOT : *End of transmission*
STX : *Start of text*

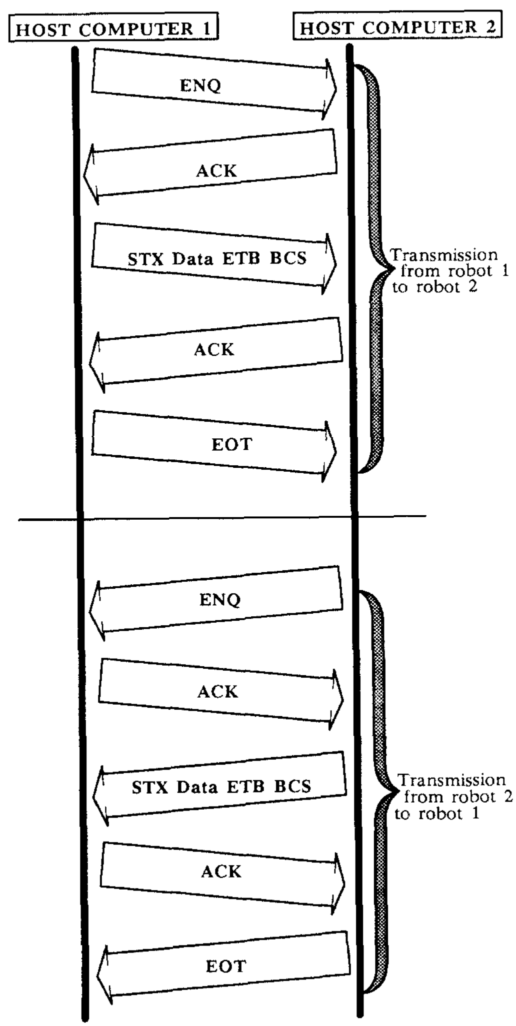

Figure 7. Binary synchronous communication

In the communication control system, the contention system is introduced to avoid data collision. When ENQ is transmitted from the both robots at the same time, collision occurs, and when this happens two different time intervals are created to prevent the collision. Data transmission starts when ENQ is received after a shorter time interval by one of the two robots. **Figure 8** shows the contention system. By this method, obstruction that happens at the enquiry transmission can be prevented.

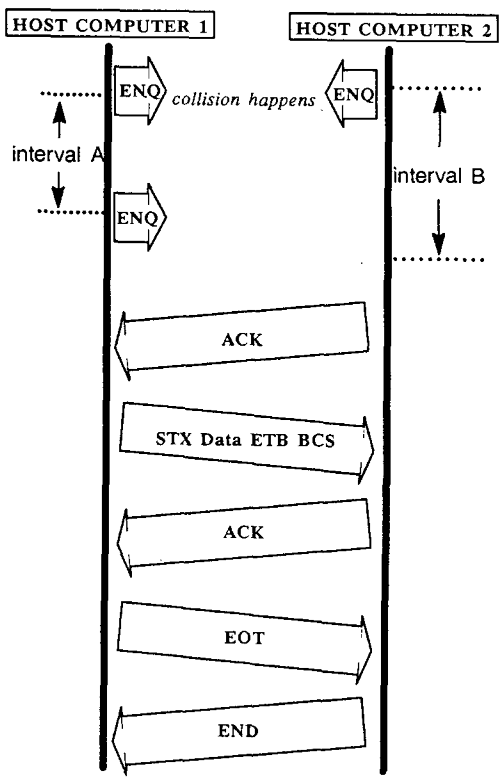

Figure 8. Contention system

7. CONCLUSION

The improvement of a mobile robot in a multiple autonomous robots system was discussed as well as the improvement on the communication between them. A mobile robot equipped with a new control circuit was developed. This has made the communication between a host computer and a robot more flexible. A reliable communication technique avoiding data collision was also deviced between host computers. As the result of this study, several defects of the former multiple autonomous robots system have been improved. A software system for cooperative work by the mobile robots needs to be developed.

References

[1] H.S.Oh, C.W.Lee and M.Ishizuka, Navigation control of a mobile robot based on active vision, IECON'91, 1991,1122-1126.

[2] E.Freund and H.Hoyer, Path finding in multi-robot systems : solution and applications, Proc. IEEE Int'l Conf. on Robotics and Automation, 1986, 103-111.

[3] C.Isik, Knowledge-based motion control of an intelligent mobile autonomous system, University Microfilms International, 1987.

[4] D.D.Grossman, Traffic control of multiple robot vehicles, IEEE-J. Robotic and automation, Vol. 4, No. 5, 1988, 491-497.

[5] IBM System reference library, General information - binary synchronous communications, 1970.

[6] Basic mode data transmission control procedures, Japanese industrial standard, JIS X 5002-1975.