Design of a Low-Cost Micro Robotic System for Developing and Validation Control Algorithms

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Abstract: This paper describes the design and construction of a micro robotic system addressing such important aspects as versatility and low cost for rapid development and test of new control algorithm. The design and structure of micro robots are presented in detail. The supervision oriented concept is designed for controlling a group of micro robots. In this concept, the vision system recognizes the environment and the host computer decides the micro robot action based on the information from the vision system. In addition, the micro robots can be implemented cheaply and small in size because the structure of supervision oriented system is simplest. The experimental results and the performance of the proposed micro robotic system are discussed.

Keywords: Micro robotic system, multiple robots control, supervision oriented concept, control algorithms

1. INTRODUCTION

Recently, micro robotic systems have been researched widely and have been applied to the variety of application fields, such as high precision production, victim detection under rubble, operation in biology and so on. The micro robots are small in size and can work in limited space. Therefore, several micro robots with useful versatilities of manipulating, tooling and gauging can be used in high precision production for small size products [1]. The researches on the micro devices, such as micro actuators, micro sensors and micro fabricating technology are necessary to build the micro robots. In addition, the control algorithms are considered to be important to realize the micro robotic systems as well [2].

Hence, this research aims to design and construct a low-cost micro robotic system for testing of new control algorithms. The overall design goal is to build low-cost micro robotic system; thus, the all components must be considered carefully in the view point of their costs. The following sections describe the construction characteristics of the micro robots, the vision system and the control method for micro robotic system. The paper also presents several practical results obtained in real time.

2. SYSTEM CONFIGURATION

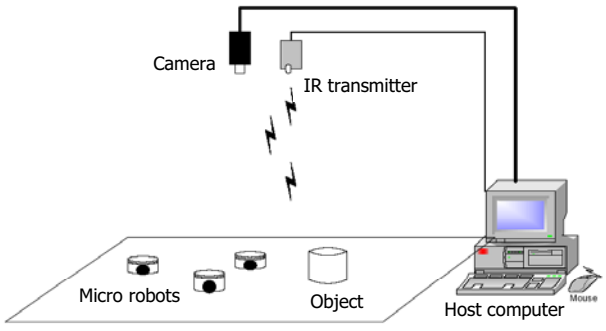

Fig. 1 System configuration.

The system configuration of the proposed micro robotic system shown in Fig. 1 consists of several micro robots, a commercial web-cam under computer control (vision system) which serves as a feedback positioning sensor, a personal computer containing the control algorithms and a transmitter that generates the control signal to the micro robots. The supervision oriented (centralized) concept is adopted in this system. In this concept, the vision system identifies the micro robots and the objects, and all data will be sent to the computer in order to decide the actions of each micro robot. By this concept, the micro robots do not require a lot of sensors, multiple way communication devices and autonomous functions [3]. Therefore, it is possible to built the micro robots with low cost and small in size.

3. DESIGN OF MICRO ROBOT

3.1 Mechanical structure

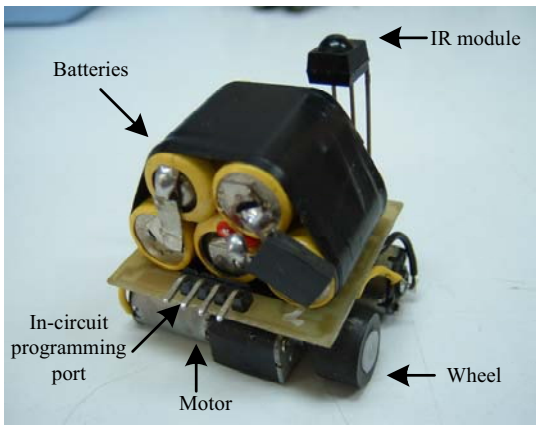

Fig. 2 Micro robot

The mechanical design of micro robot consists of two wheels, two dc motors, batteries and control circuit as shown in Fig. 2. The size of each micro robot is approximately 3 x 3 x 3 centimeters. Two motors are located in front and rear in

such a way to reduce the size of the micro robot. A reduction gear head is assembled together with the motor in the factory. The micro robot has two wheels in its right and left sides. The direction control is achieved by difference the wheel speed of each side, which is illustrated in Fig. 3.

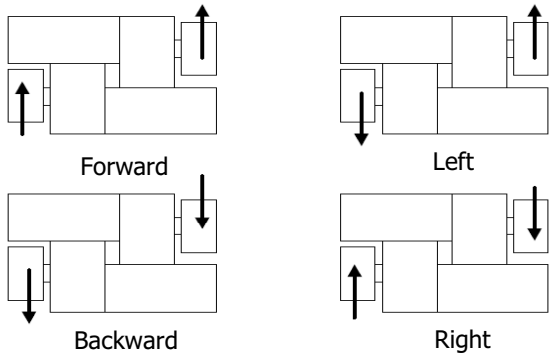

Fig. 3 Direction control.

For simple assembly, the designed micro robots have no body frame, thus the control circuit and the batteries are attached on the top of the motors by double-size adhesive tape.

3.2 Control circuit

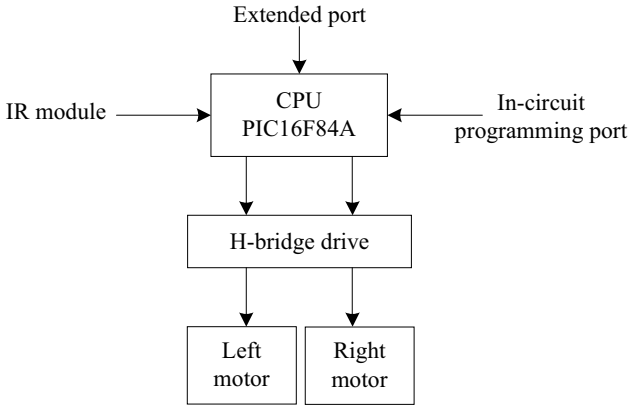

Fig. 4 Structure of control circuit.

Fig. 4 shows the structure of control circuit. Each micro robot is equipped with its own CPU in order to receive the sensor signal, decode the control data from the host computer and control the direction of the micro robot. In this work, an Microchip 8-bit microcontroller PIC16F84A (SMD) is used. The programming for robot control and communication is developed by PIC Basic complier and stored in the flash memory. The programming can be modified easily via the in-circuit programming port. Moreover, the special tools or circuits such as a micro gripper, obstacle avoidance sensors and so on, can be implemented on the micro robot via the extended port so that the micro robot can do a specific function. In order to control speed and direction of the micro robot, the CPU generates the control signal through its port, and this signal is amplified by using four transistors (2SD569) arranged in an H configuration around the motor (H-bridge drive). The motors and the circuit are supplied by 6V Ni-Cd re-chargeable batteries. The control circuit is illustrated in Fig. 5.

3.3 Communication system

The communication system is necessary for data transmission between the host computer and the micro robots, especially a wireless communication. The size and cost are the key factors in choosing the communication system. Thus, an IR communication is adopted in this work because it is simpler and smaller than RF communication. The IR communication shown in Fig. 6 has two modules: a transmitter and a receiver. The transmitter is connected to the host computer and sends the control data to the micro robots. The serial communication protocol is used for data transmission. The serial data will be modulated by carrier frequency of 38KHz before sending via IR-LED in order to protect the ambient light. The IR module on each micro robot will receive the modulated data, eliminating the carrier frequency and then sending the control data to the CPU.

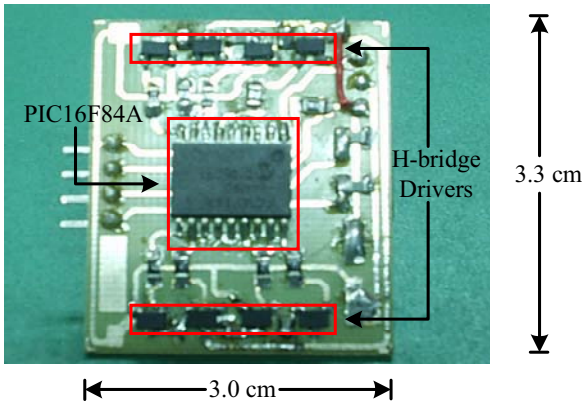

Fig. 5 Control circuit

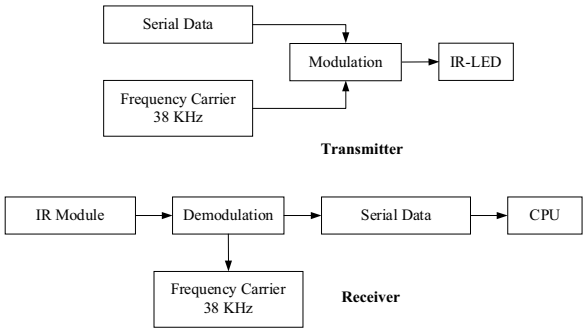

Fig. 6 IR communication.

4. CONTROL OF MICRO ROBOTIC SYSTEM

There are various methods to control the micro robotic system [4]. The selection of control methods depends on (1) the hardware such as structure of micro robots, sensors and actuators, (2) the software for control algorithm and strategies and (3) system integration. Basically, the micro robotic system needs micro robots, a vision system, a host computer and a communication system. In this research, the control method will be selected based on the simplicity of system integration and the device costs. Thus, the supervision oriented system will be adopted in this system. By this concept, the micro robots need only actuators, communication part and CPU as previous stated in section 3. All the calculations of image processing, position control of

micro robots and so on are managed by the host computer. Consequently, the micro robots can be implemented cheaply. The computational time on the CPU of the micro robots can be reduced and results in faster action cycle. The overall system performance can be improved. However, the host computer needs high computational power for positioning and controlling the positions of multiple micro robots accurately.

4.1 Vision system

In this research, the use of the web-cam (QuickCam Express, Logitech) under computer control is the core of an inexpensive vision system for the supervision oriented system. The camera is located above the center of field to identify the positions and orientations of micro robots and the positions of obstacles. Then it sends all the data to the host computer via a USB port. To distinguish each of micro robots and calculate their position and orientation, the color marks will be set up on the top of micro robots. It consists of two different color marks in the front side and the center of each micro robots. Each micro robot has the same white color marks in the front side and the different color marks (red, yellow and blue) in the center. The micro robots with color marks are shown in Fig. 7. The position of each micro robot can be recognized by the color marks in the center. In addition, the orientation can be also identified by a straight line from the color mark in the front side to the color mark in the center.

Fig. 7 Micro robots with color marks.

4.2 Host computer

Based on the supervision oriented system, the computational speed of host computer is critical in the control of multiple micro robots. A Celeron-800MHz personal computer is used as the host computer. The image information of micro robots can be obtained by the vision system and sent to the host computer. Then, the host computer will calculate the orientation and position, decide a path, and generate the control signal for each micro robot. The control signal is sent to the micro robots via the IR transmitter which is connected to the parallel communication port.

4.3 Cooperative multi-agent system

The cooperative multi-agent system is an important part to manage the multiple micro robots in cooperation. It consists of basic algorithms and special algorithms. The basic algorithms are “move” and “obstacle avoidance” behaviors. Each micro robot has the same basic algorithms. On the other hand, the special algorithms can make the micro robots play the complex performance such as gathering the object, moving in a line of troops and so on. In this research, the rule-based system is adopted to design the cooperative multi-agent system. At every sampling time, the cooperative multi-agent system gets the position of micro robots, decides the algorithm, then informs the coordinates of the destination to the micro robots. The sampling time of the cooperative multi-agent system is determined by the data update time from the vision system.

5. EXPERIMENTAL RESULTS

All the sub systems of the proposed micro robotics system have been integrated and tested. The control algorithms are realized in a program written in Visual Basic program. The graphic user interface (GUI) shown in Fig. 8 is also developed by this program in order to enables direct teleoperation of the micro robotic system. In this section, the examples of several simple control algorithms, which demonstrate the independent and group controls of micro robots are performed.

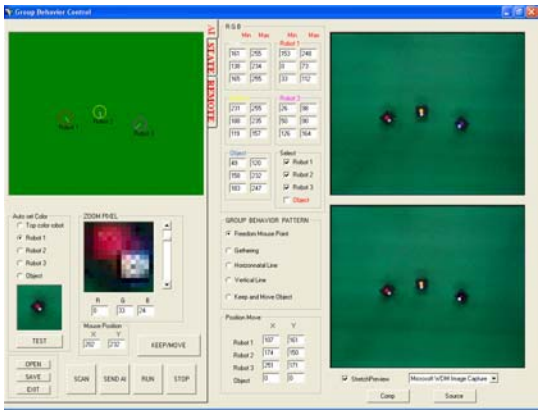

Fig. 8 GUI for micro robotic system.

5.1 Independent control of micro robots

Three micro robots are placed on the field under the camera. The operator or the host computer can inform the coordinates of the destination to each micro robot independently through GUI. The trajectories of each micro robot are captured and plotted as shown in Fig. 9.

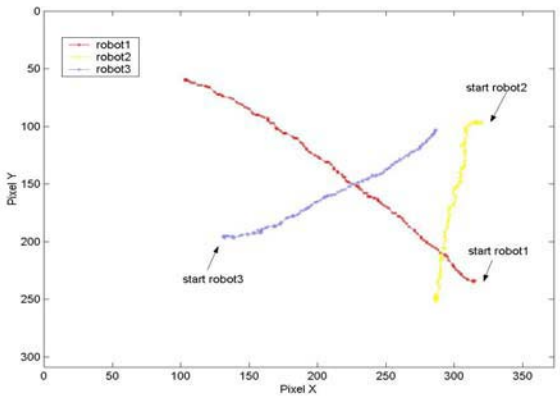

Fig. 9 Independent control of micro robots.

5.2 Gathering the object

The motion of micro robot for gathering the object is illustrated in Fig. 10. The micro robot first moves from the starting point to the first destination in order to the avoid the object, then rotates its orientation toward to the final destination. Finally, the micro robot moves to the final destination with the object. The trajectory are plotted as shown in Fig. 11.

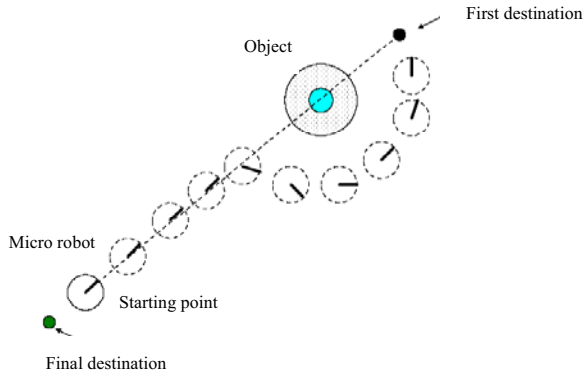

Fig. 10 Moving pattern of micro robot for gathering the object.

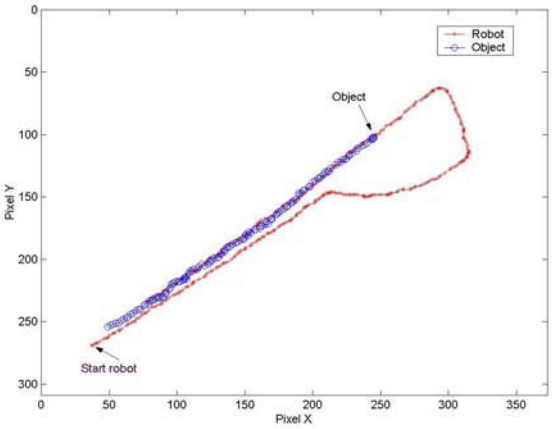

Fig. 11 Gathering the object.

5.3 Group control of micro robots

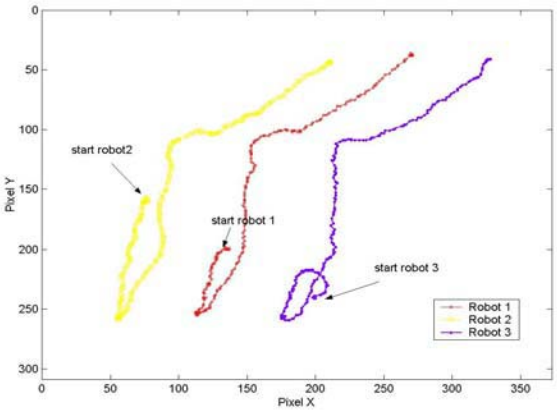

Fig. 11 Group control in a line of troops.

For the practical applications of micro robotic system, one of important performances is to control the multiple micro robots in cooperation to do the specific tasks. The moving in a line of troops and moving in a triangular pattern algorithms are developed here to demonstrate the simple group control of multiple micro robots. The experimental results of group controls in the line of troops and in triangular pattern are respectively shown in Fig. 11 and Fig. 12.

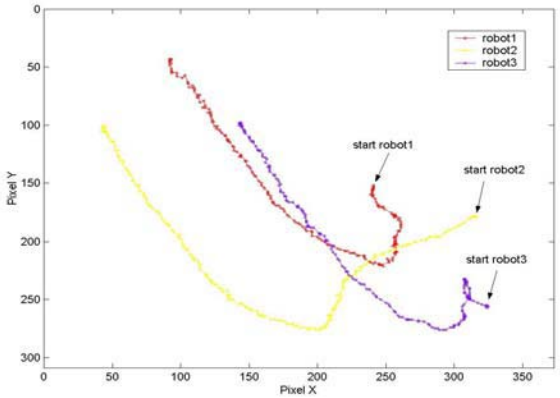

Fig. 12 Group control in a triangular pattern.

Based from the experimental results, it was observed that there are the position and orientation errors of the micro robots. However, it is acceptable in a range of applications.

6. CONCLUSION

This paper described a versatile and economic alternative for developing the micro robotics system in order to make it possible to design and test new control algorithm for the group of the multiple micro robots. The vision system based on the web-cam under computer control is simple to install and operate with acceptable accuracy. Several experimental results were performed both of the independent and group controls of micro robots.

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