Multi Agent Micromanipulation System

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Abstract *– In the area of biotechnology, a micromanipulation is widely used for such purposes as operating on genes and transferring biological materials into cells. For the some experiments, such as biochemical experiment, a large number of cells have to be manipulated in a short time. We have developed an automatic micromanipulation system under the stereoscopic microscope. Micromanipulation system carries out various processes, such as detection of the target, the detection of the needle head, and motor control. By sharing these processes with several computers, the micromanipulation can be performed at high speed. As a result, computer cooperation becomes very important. In this paper, we propose a multi agent micromanipulation system. At first, we developed a multi agent system, which performs image processing, motor control, and management of the micromanipulation processes. Secondarily, we proposed to operate computers cooperative. We use a computer as a single agent. And several computers are connected to a local area network. The multi agent micromanipulation system performed the micromanipulation at a realistic rate through cooperation of multi agents.*

Keywords *– Micromanipulation, Stereoscopic Microscope, Stereo vision, Image processing*

I. INTRODUCTION

In the area of biotechnology, a micromanipulation is widely used for such purposes as operating on genes and transferring biological materials into cells. For the some experiments, such as biochemical experiment, a large number of cells have to be manipulated in a short time. We have developed an automatic micromanipulation system under the stereoscopic microscope. Micromanipulation system carries out various processes, such as, detection of the target, the detection of the needle head, and motor control. By sharing these processes with several computers, the micromanipulation can be performed at high speed. In this paper, we propose a multi agent micromanipulation system. At first, we developed a multi agent system, which performs image processing, motor control, and management of the micromanipulation processes. We use a computer as single agent. And computers are connected to a local area network and operate cooperatively. The multi agent micromanipulation system performed the micromanipulation at a realistic rate.

II. METHODS

Figure1 shows a multi agent based micromanipulation system. The system consists of a stereoscopic microscope, two CCD cameras, a micromanipulator and 4 personal computers. Computers are connected to the local area network and those computers acts as an individual agent. Fig. 2 shows roles of the micromanipulation agents. The multi agent system consists of a management agent, 2 image processing agents and a motor control agent. Computer2 and computer3 are image processing agents. Figure 3 shows a role of the image processing agent. The algorithm of the image processing agent is as follows.

Step 1: Receive the command from the management agent.

Step 2: Input the camera image using a video capture unit.

Step 3: Detect the needle head and the target using image processing algorithms such as median filtering, thresholding procedure and labeling procedure. The target and the needle head are detected by their color and shape information. The shape information consists of the size and the normalized area. The normalized area is the square of the contour length over the size. Sizes and contour length of extracted pixels are estimated by labeling. The needle head is identified from its shape information.

Step 4: Send the information about the positions of the needle head and the target to the management agent.

The management agent receives the positions of the needle head and the target in the left camera image and the right camera image. The position of the needle head is estimated three dimensionally using the stereovision method. Figure 4 shows principle of the stereovision method. The distance from the camera to the needle head *yp* can be estimated as follows.

$$y_p = \frac{f \bullet d}{x_l - x_r} \tag{1}$$

where x_l is the position of the needle head in the left

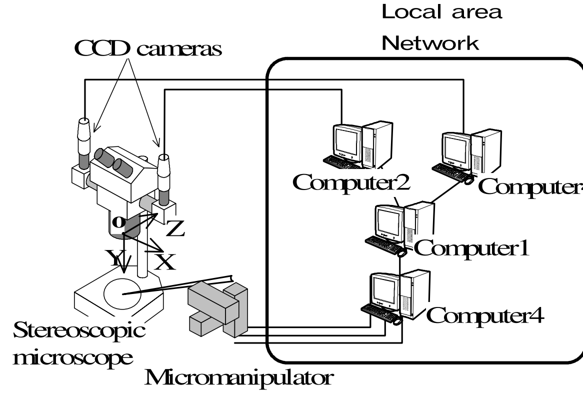

Fig.1 Multi agent micromanipulation system.

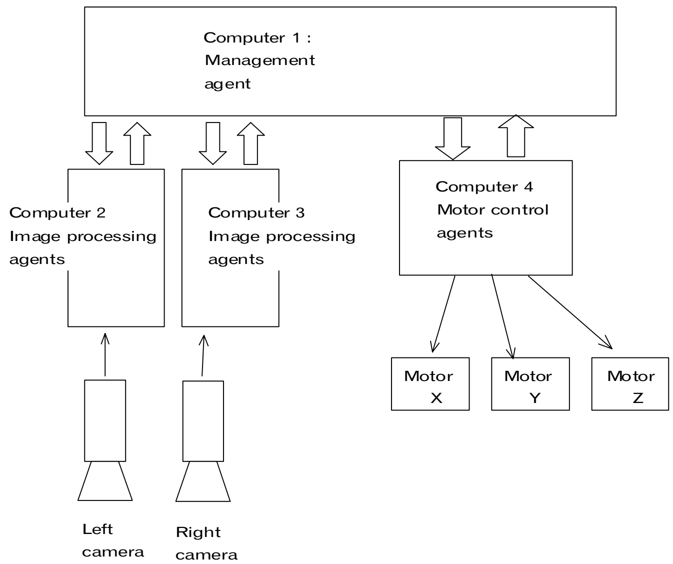

Fig.2 Roles of micromanipulation agents.

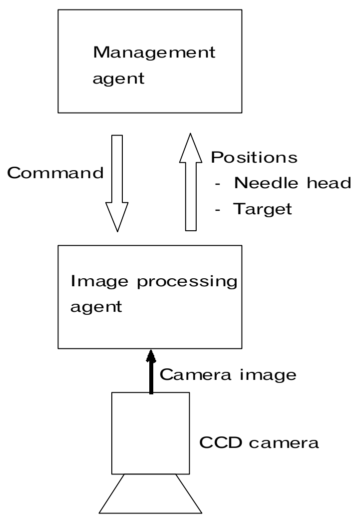

Fig.3 Role of the image processing agent.

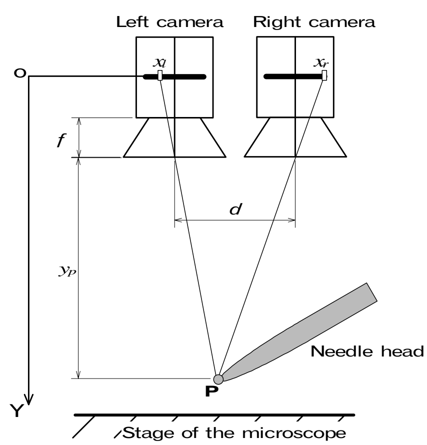

Fig. 4 Stereo vision method.

camera, x_r is the position of the needle head in the right camera, f is the focal distance of the camera and the d is the distance between the left camera and the right camera.

After calculating the distance between the needle head and the target, the management agent sends a command to the motor control agent.

Computer4 is a motor control agent. Figure 5 shows the role of the motor control agent. The algorithm of the motor control agent is as follow.

Step 1: The motor control agent receives the command from the management agent with the moving direction and the moving length.

Step 2: The motor control agent moves the motor X, motor Y and motor Z.

Step 4: The motor control agent sends the message to the management agent after finishing the needle head movement.

The management agent controls the image processing agents and the motor control agents based on the moving strategy. We propose three ideas in the strategy of moving the needle head.

1) A path of the needle head
2) Estimation of moving length of the needle head.
3) Selection rule of a size of the image data

We set a path of the needle head as shown in figure 6. The point o is a position of the needle head at the beginning of manipulation. The point o1 indicates a limit of the area

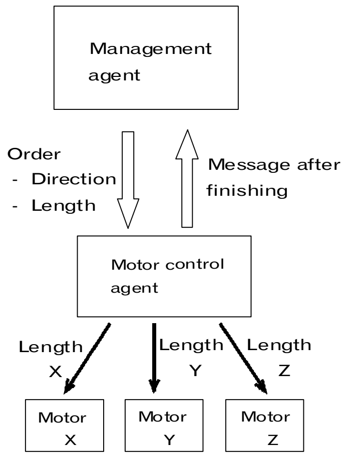

Fig.5 Role of the motor control agent.

coming into focus. The limit of the area is experimentally estimated. Since the image of the microscope is narrow in focal depth, the needle head in the image is unclear at the beginning of the manipulation. The needle head should be guided to be in focus. The needle head descends vertically to the height of the goal (between o and o2). After that, the needle head moves horizontally (between o2 and c). With this path, the most part of manipulation is performed with the needle head clear in the image.

During the needle head is unclear in the image, we should perform the manipulation carefully. We decided a very short moving length of the needle head. After the needle head moving the length, the image acquisition is performed again.

The moving length M is estimated as follows.

$$M = r \times D \qquad (2)$$

where M is the moving length, D is the distance between the needle head and the destination and r is constant which value is less than 1.0. While the needle head is unclear in the image (between o and o1), the needle head should be guided slow in order to achieve fully control of the needle head position. When the needle head is in focus, the needle head is clear in the image. We set the r as 1.0 while the needle head is clear in the image (between the o2 and the b).

It takes a lot of time for image processing in visual feedback. For reduction of the image processing time, we use two sizes of image data. One is full-size of CCD image data and the other is small one. When the needle head is between o and the o1, the small image data is used for the image measurement. The small image is used when the needle head is between the o2 and the a too. In each case, it is not so important to measure the distance at high resolution because the needle head is far from the stage or is far from the target. Furthermore, during the needle head moves parallel to the stage, the distance between the needle head and the target is measured two dimensionally with the right image.

The algorithm of the management agent is as follows.

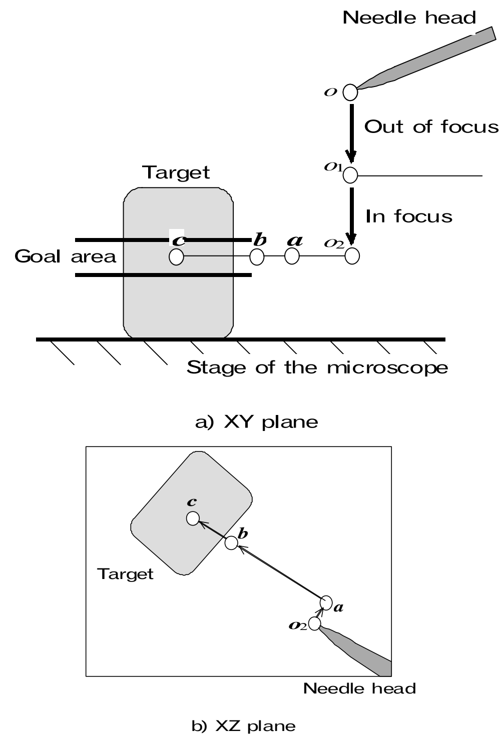

Fig.6 Strategy of moving the needle head.

i) The management agent receives a goal of the needle head, color and shape information of the target and the needle head from operator.
ii) The management agent decides the sizes of the images and the dimensions of the positions of the needle head and the target with the strategy of moving the needle head.
iii) The management agent requests the positions of the target and the needle for the image processing agents.
iv) The management agent receives the positions of the target and the needle head from the image processing agents.
v) The management agent decides the moving direction and the length of the needle head according to the condition of the micromanipulation. The conditions of the micromanipulation and the moving direction and the length are as shown in table 1.
vi) The management provides the moving direction and the moving length to the motor control agent and requests moving the needle head.
vii) The management agent receives the notification after finishing the movement of the needle head.
viii) The management agent checks if the needle head reaches the goal. The process from i) to v) are performed so that the needle head reaches the goal.

As the result, the needle head can approach the target in a short time.

Table 1 Control rule of the micromanipulation.

Condition of micromanipulation	Moving direction	Moving length
a) The camera image is unclear.	Vertical (Y axis)	Small : r=0.82
b) The needle head is far from the target in height	Vertical (Y axis)	Large : r=1.0
c) The needle head is far from the target but the height is almost the same as the target.	Horizontal (X,Z axis)	Large : r=1.0
d) The needle head is near to the target.	Horizontal (X,Z axis)	Small : r=0.82:
e) The needle head pierces the target.	Needle head direction	Small : r=0.82
f) The needle head reaches the goal.	Stop	

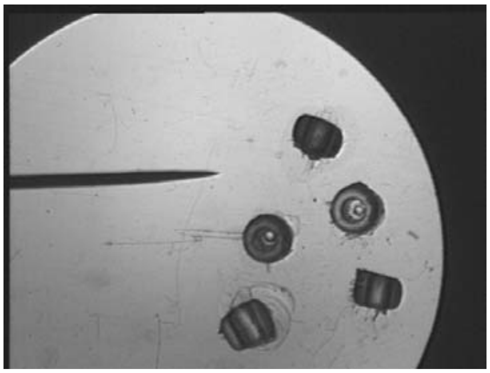

Fig.7 Needle head at the home position.

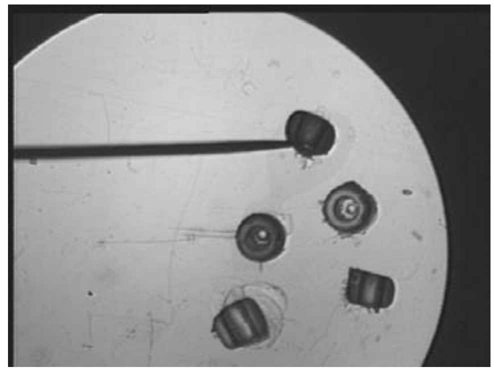

Fig.8 Needle head reaches the target.

Table 2 Measurement resolutions .

x	0.0042 mm
y	0.0167 mm
z	0.0041 mm

III. RESULTS

The magnification of the microscope is set at 10 times. A measurement resolution is derived as shown in table 2. Fig. 7 shows the plastic beads and the needle head at the beginning of the micromanipulation. We choose a plastic bead as a target. The target is 2.4 mm in diameter and 1.4 mm height. The micromanipulator is controlled automatically so that the needle head should reach the center of the target as shown in Fig.8. The 4 times of image measurement was performed when the needle head moved from home position o to o2. The required time for the image processing is 6.31 seconds with the micromanipulation system which 1 computer was used for. On the other hand, the time required at this time was 1.96 seconds with a multi-agent micromanipulation system. As the result, it became clearer that the multi-agent micromanipulation could perform at high speed.

IV. CONCLUSIONS

In this paper, we propose a multi agent micromanipulation system. At first, we developed a multi agent system, which performs image processing, motor control, and management of the micromanipulation processes. Secondarily, we proposed to operate computers cooperative. We use a computer as single agent. And computers are connected to the local area network. The multi agent micromanipulation system performed the micromanipulation at a realistic rate.

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