Development of Micro-Object Position Detection System for the Automation of Robot Hand

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Abstract

Aiming to realize the automation of the operations of micro object micromanipulators in this study, we developed a system for operating micro objects composed of a gripping robot, x-y stage, CCD camera and control PC. In addition, we also applied the template matching method to detect objects from images. Investigations on the positioning accuracy of the developed system showed that the accuracy error of positioning was found to depend on height of the object.

1 Introduction

Recently, the miniaturization of products and their components is progressing at a very fast pace in various industries. Examples include microbes and cells in the area of biotechnology. Microorganisms in such areas are usually operated manually with manipulators, but such operations require skilled operators, who take considerable time and cost to train up. One solution to resolve this problem is the automation of the micro-manipulator. To realize this, there is first a need to accurately identify the position and shape of the object being operated, and then calculate the amount of manipulation work required. The purpose of this study was thus to develop a system which can identify the position and shape of objects by image recognition, automatically position the objects using the x-y stage, and operate them using the gripping robot.

2 Outline of system

2.1 Structure of micro object manipulation system

Fig.1 shows the structure of the micro object operation system. The system developed is composed of a gripping robot, x-y stage, CCD (Charge Coupled Device) camera and control PC. First, the system moves the target object on an x-y stage, then grips and carries it with gripping robot. The maximum operating range of the x-y stage is 20mm and the resolution is 10nm. These are driven by the control pulse and control signal from the pulse operation. The CCD camera is placed directly on the x-y stage to check the status and position of the object on the stage by image recognition. Images of the object are then input from the camera to the control PC through the capture board. The resolution of the input images is 640 × 480dpi.

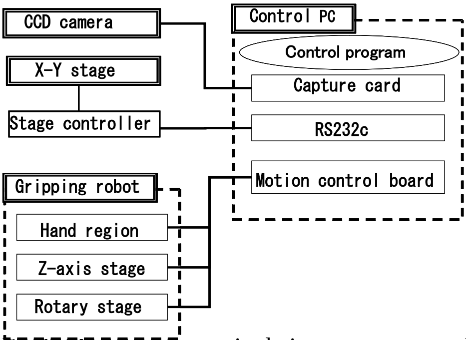


Fig.1 Micro object manipulating system

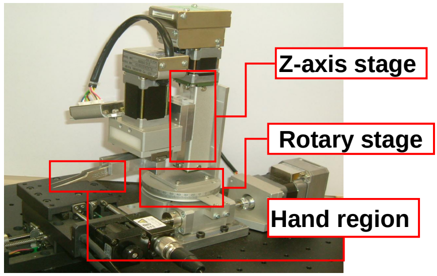


Fig.2 External view of a gripping robot

2.2 Structure of a gripping robot

Fig.2 shows the external view of the gripping robot. This robot is SCARA type with degree of freedom 2, composed of the hand region, z-axis stage and rotary stage. The hand region is attached with a pair of tweezers used for manipulating switching and gripping operations. A stepping motor is used for the servo motor.

3 Gripping operation of micro objects

3.1 Automatic positioning by image recognition

The first step of the gripping operation is to measure the position of the micro objects placed on the x-y stage. The template matching method was also applied in this system to recognize the position of objects. The template matching method is a technique for deciding the presence of objects by comparing the input image and the template image pixel.[1] In this study, we used the degree of similarity calculated by normalized cross-correlation matching, and determined the presence of objects from the degrees of similarity ranging from 0 to 1 obtained the whole image. Based on this method, the position of the object on the image can be identified and the position of the moving object and relative distance can be calculated from the image unit. Due to the need to specify the operations of the x-y stage in μm units, the distance moved in was calculated by multiplying the distance per pixel with the width per pixel.

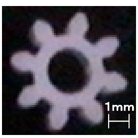
3.2 Movement of the gripping robot

After moving the object to the operating range of the gripping robot by automatic positioning, the gripping robot grasps and carries the object. First, the rotary stage is operated and the tweezers are moved directly above the object. Then z-axis stage is lowered to match the height of the object. Finally the hand region is closed. The above procedure is repeated a number of times.

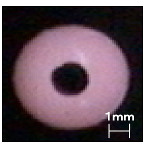
4 Highly precision image recognition

4.1 Current image recognition accuracy level

Positioning is performed based on image recognition on information only. Thus the actual positioning accuracy depends on accuracy of image recognition. To investigate the accuracy, we moved an object on the stage by automatic positioning movement and measured the distance moved and verified accuracy. First, an object was placed on the x-y stage. Fig.3 shows the target objects; a gear measuring 5mm in height and 5mm in width and beads of 5mm in diameter. The positioning target was specified with the current position of the object on the stage as the origin. Next, the x-y stage was operated manually and moved for the distance equivalent to the theoretical value of positioning. This action moves the x-y stage to the position of origin. The distance between the origin and position moved to by the stage at this time is taken to be the error. This procedure was repeated while changing the amount of positioning in the range of 100μm to 5mm in respect to the x axis for each measurement made every 50 to 100μm. Fig.4 shows the results. Here, as the theoretical maximum error is about 113μm when the gear theoretical value was 3.6 mm, and 36μm when the bead theoretical value was 4.8mm. In the case of gears, their shape change and similarity vary while the stage is moving, which causes errors to become conspicuous.



(a) Gear



(b) Bead

Fig.3 Target objects

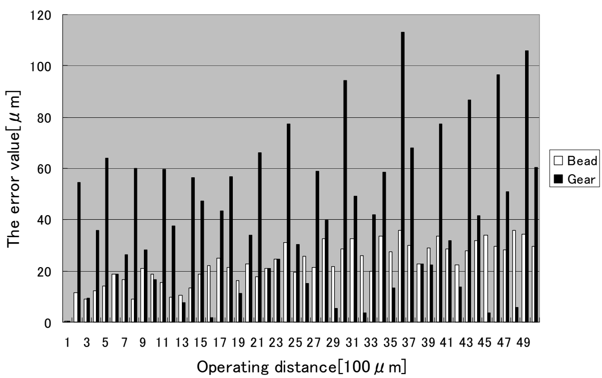


Fig.4 Positioning error of gear and beads

4.2 Verification of effect factors of positioning accuracy

In normalized cross correlation matching, clear uniform changes in the image are not affected that much because the results have been normalized. This means that accuracy is affected by other factors. With this system, as the CCD camera is fixed just above the x-y stage, the position of the object changes according to the operations of the stage as shown in the experiment results described earlier. Fig.5 shows the objects used in experiments on the effects of the object height on positioning accuracy. The objects are plastic cylinders with the same diameter of 2.5mm, but with different heights; 1mm, 2mm, 3mm, 4mm, 5mm. Like the previous study, they were placed on the stage and moved automatically to their target positions. Fig.6 shows the measured results. The average error was found to be proportional to the maximum height, confirming that the height affects positioning.

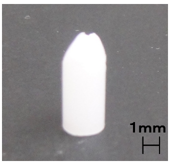


Fig.5 Plastic cylinder

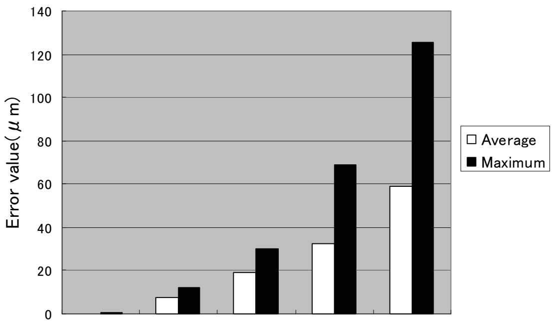


Fig.6 Error value of the height of the cylinder

5 Conclusion

In this study, we developed a system for positioning micro objects, and conducted positioning experiments by image recognition to verify its operations. The following conclusions were obtained.

(1) The maximum automatic positioning error of used this system is about 113μm.

(2)Automatic positioning accuracy was found to depend on the height of the object.

In the future, we hope to improve image recognition algorithms to realize more precise positioning, as well as automate the operations of the gripping robot.

References:

[1] T. Fukutaki, Y. Kobayashi, K. Shirai: Development of a Position Detection System Applying to a Micro Manipulator for a Microscopic Object, J,2007 JSPE Spring Meeting(2007), pp.472-474(in Japanese).