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# Application of Automatic Zooming and Autofocusing in Microassembly using Visual Servoing

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## 1. Introduction

In recent years, many industrial products and their components are evolving toward miniaturization. To have more functionalities within less dimensional volume, they are usually made of various materials with different characteristics, and they are manufactured using incompatible manufacturing processes with complex geometrical shapes. For these reasons, the assembly technique for mating micro-parts so called microassembly has become important for advanced manufacturing and drawn extensive research interest. Currently, due to various difficulties arising from handling of extremely small size parts, manual assembly method has been widely used [1]. Since this manual method is somehow time-consuming and not productive enough, automation of micro-assembly has become an essential part for micro parts manufacturing. As an alternative, the vision sensor is widely used in microassembly. The vision sensor has a wide field of view, and it can obtain the wide range data with high speed without contact. In the previous research works, the orientation of the mating parts has not been considered for corrective motion, and, furthermore, the developed vision systems are not adaptive to accommodate various sizes of the mated parts To avoid such criticism, we propose a visual feedback system that accommodates micro parts of various sizes and parts arbitrarily oriented. In this paper, the system that employs adaptive zooming and autofocusing techniques during visual servoing is described.

## 2. Systems and Autofocusing

### *2.1 Microassembly Systems with zoom lens*

Generally, high magnification lens is required for microassembly. High magnification lens has small field of view and extremely small depth of field as well. The magnification problem is solved by using a motorized zoom lens which can change the field of view and the small depth of field problem is solved by autofocusing method.

Figure 1 shows the proposed system for microassembly. This system is equipped with two types of illumination

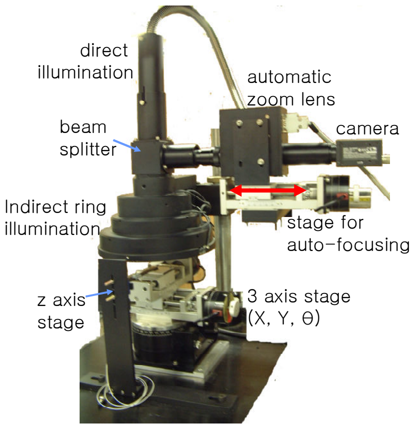


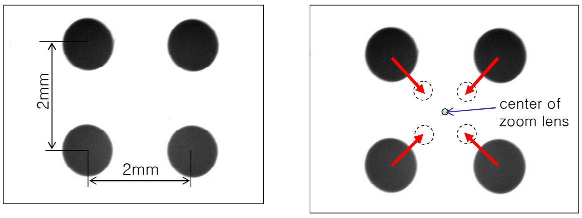

Figure 1. The proposed system for microassembly

which are direct and indirect, camera with a zoom lens, autofocusing unit and a four-axis stage for manipulating micro parts shown in the lower part of the figure. In the manipulating stage, the lower micro part is made to move along a three axes stage which consist of X, Y and θ axes while the upper micro part is made to move along Z-axis only. This four degrees of free motion with instantaneous visual information feedback makes it possible to achieve an accurate alignment between the two parts, making them ready for assembly action. Since the tilting angle mismatch between the two micro parts is negligibly small in this systems, the tilting corrective motion is not considered for assembly action.

### *2.2 Calibration of Zoom Lens*

In order to apply visual servoing technique to this assembly system, the relationship between the motion of parts in the image plane and the motion of parts in the task space (X, Y, Z) should be analysed. Particularly, we need to calibrate magnification of zoom lens varying along relative motor motion, and find optical zoom center in image plane. In the zooming action, the image is zoomed along optical zoom center, rather than the center of image.

To determine these, a pattern of four solid black circles 2 mm apart are employed as shown in Figure 2(a). As the lens motion is zoomed out, these solid black circles are shown to move toward the optical center of the lens as shown in Figure 2(b). The crossing point of the four lines can be defined as the optical center of zoom lens because it does not move in both of the zoom in or zoom out. From this experiment, the point of (358.5, 292.0) is obtained in the pixel coordinates.




(a) calibration pattern (b) four line trajectories by zooming out motion

Figure 2. Calibration of optical zoom center

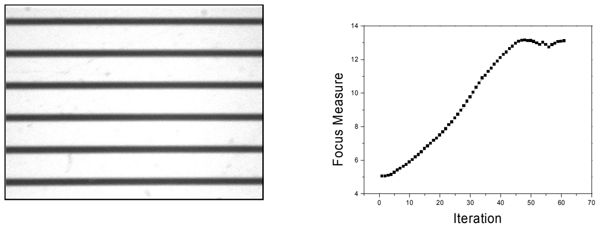
In order to calibrate the magnification of zoom lens, the change in magnification is measured in accordance with the step of the stepping motor to drive zoom lens. From experimental result, it can be seen that the magnification of the zoom lens varies from 0.22 to 1.3. The curve representing variation of the magnification was fitted to a 2nd order polynomial curve as follows;

$$m = 2.23\times10^{-1} + 8.31\times10^{-3} n + 7.94\times10^{-4} n^2 \qquad (1)$$

where $n$ denotes the step number of the stepping motor actuated for zooming.

*2.3 Autofocusing*

In this visual servoing, geometric features indication of the position and orientation of the two mating parts are used, as the method are used in other researchers' works. Obtaining accurate and clear image of them is important to determine the information of their instantaneous positions and orientations. In general, a lens with high magnification inherently has short depth of field. In out-of-focused range, blurred image is usually obtained. In this situation, the features needed for localizing an object cannot be extracted accurately. In order to obtain their accurate features, we need to instantaneously adjust the focal point of the zoom lens by controlling its position relative to the object along the optical axis as shown in Figure 1. Here, we apply an autofocusing algorithm which essentially controls the distance between the object and the zoom lens of the camera according to a focus measure: Because the focus measure represents the degree of the in-focus state [2]. It is important to select an appropriate focus measure to achieve high performance autofocusing. In this study, we used a focus measure which is obtained from the standard deviation of the Sobel edge detection value, operated in the interested region of the image enhanced by the median filter [2][3]. This focus measure is evaluated by using a line stripe pattern as shown in Figure 3(a) and calculated by varying the distance between the objective lens and the pattern. Since it is necessary to determine the focal point in an on-line manner, the hill-climbing method [4] is applied in order to find the position of camera with the peak value of the proposed focus measure. Figure 3(b) shows variation of focus measure during autofocusing.




(a) Stripe Pattern (b) Variation of Focus measure during autofocusing

Figure 3. Autofocusing pattern & focus measure

## 3. Conclusion

We studied a new microassembly method which utilizes a high precision, visual servoing technique with automatic zooming. In order to utilize zoom lens, we need to find optical zoom center and magnification. Also, in order to solve the problem of short depth of field in high precision optical system, we used autofocusing algorithm and median sobel filter robust to noise as a new focus measure.

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