International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.12, (2016), pp.29-36
http://dx.doi.org/10.14257/ijsip.2016.9.12.04

Measurement and Assembly of Microminiature Parts Based on Micro Machine Vision

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Abstract

With the development of modern high precision processing technology, precise microminiature electromechanical products have been widely used. Most of the precise microminiature electromechanical products are assembled from microminiature parts.Due to dimensions of the microminiature parts involved are in micro-and nanoscale, which cannot be reached by ordinary cameras, it cannot effectively capture the image of those parts to be assembled, thus affects the assembly. A microscopic vision measurement system of stereo microscope that combined with high resolution CCD camera was developed based on micro machine vision, which uses the MATLAB software to deal with the collected images of microminiature parts such as image smoothing, image sharpening, image segmentation and edge extraction, etc. to study the structures, identification, location and assembly process of microminiature parts. The results show that the visual system we used has accomplished the automatic measurement and precise assembly of miniature parts excellently.

Keywords: *micro machine vision; microminiature parts; MATLAB; image analysis; measurement and assembly*

1. Introduction

With the development of modern high precision processing technology, a large number of precision microminiature electromechanical products are are widely used in the field of aerospace, industrial, biological, medical and military .However, the related process and connection technology of these microminiature electromechanical products are different, it is hard to achieve a specific function by a single process. It is mainly assembled from microminiature parts. Therefore, assembly is the key and the most difficult problem in this type of manufacturing industry, which needs the corresponding measurement and assembly technology simultaneously. Nevertheless, with the development of miniaturization technology, the feature size of measurement and assembly of micro parts are becoming more and more important in micro-and nanoscale. Micro operating system has become an indispensable tool for people to explore the microscopic world, miniaturization technology is one of the important dual-use technology, and the development of which has profound influence on the development of civilian and defense-related technology. So it is of great significance for the development of microminiature manufacturing technology and the research of the measurement and assembly technology of microminiature parts.

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ISSN: 2005-4254 IJSIP

Combined with the micro machine vision and automatic control technology, the research and development of the control methods and techniques has already applied to the measurement and assembly of microminiature parts at home and abroad since 1990s'. The complex micro system of Micro assembly [1] technology is composed of many microminiature parts that are accurately positioned and manipulated. The superiority of micro assembly which based on micro machine vision is that it provides higher visual measurement accuracy and assembly precision, ensures the quality of products and increases productivity. According to the research on the microminiature parts precision assembly at home and abroad, a great variety of products that applied the micro assembly and micro manipulation related technology has been developed, such as the corresponding visual micro positioning, parallel robot, all kinds of micro gripper and dynamic observation. Due to dimensions of the microminiature parts are in micro-and nanoscale, which cannot be reached by ordinary cameras, it cannot effectively capture the image of those parts to be assembled, the measurement and assembly tasks are carried out by using the microscopic vision measurement system of stereo microscope that combined with high resolution CCD camera in this paper.

2. Structuring of the Micro Assembly System

According to different size of microminiature parts and assembly function, assembly system [2] of microminiature parts is usually made up of computer control and human-computer interaction module, manipulator module, parts feeding module, precision adjustment module and vision measurement module, computer control and human-computer interaction module. Schematic model of the structure of the micro-assembly system is shown in Figure 1. Manipulator module consists of a clamp and a sensor, which achieves the gripping and releasing of parts and completes the assembly process.The parts feeding module and precision adjustment module consist of the motion platform, fixtures, the locking mechanism of parts, and then complete feeding and assembly.Visual measurement module consists of the stereo microscope , high resolution CCD camera, light source lighting and three dimensional precision motion platform, completed parts of the image acquisition and identification and location of parts to be assembled to realize precise measurement of the location of parts. Computer control and human-computer interaction module is mainly composed of control panel, I/O control card and interactive control program module to help the operating personnel make a correct judgement of the feedback information of the system and issue the next control instruction.Stereo microscope is shown in Figure 2.

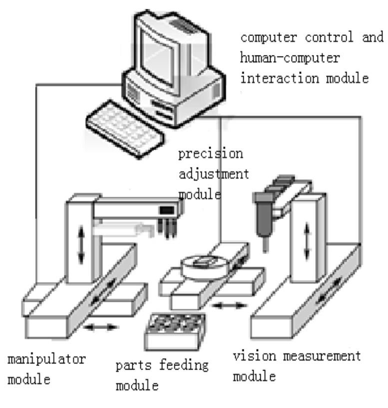


Figure 1. Structure of Miniature Parts Assembly System

Figure 2. Stereo Microscope

Measurement and assembly for microminiature parts can be divided into loading, identification and location of parts and precision assembly of parts. High resolution CCD camera combined with stereo microscope are used to capture the original image of target parts in different locations and then some methods such as image smoothing, image sharpening, image binarization are used to process the original image to complete the identification and localization of parts to be assembled to achieve the coordinate position of parts to be assembled and to drive work machine hand to grip and assemble parts to complete the assembly operations accordingly .In this paper, the microscopic magnified parts are threaded hole and bolt, as shown in Figure 3.

part1 part2

Figure 3. Assembled Parts of Microscopic Enlarged

3. Automatic Measurement and Precise Assembly of Microminiature Parts

Due to dimensions of the microminiature parts involved are on micro-and nanoscale, which cannot be reached by ordinary cameras, it cannot effectively capture the image of parts to be assembled, the measurement and assembly tasks were carried out by using the microscopic vision measurement system of stereo microscope combined with high resolution CCD camera.

Automatic measurement and assembly system of microminiature parts based on micro machine vision are used to achieve Automatic measurement and precise assembly of microminiature parts by collecting magnified images of microscopic, identification of calculator and location and output signal to the sensor device of microminiature parts.The whole process is shown in Figure 4.

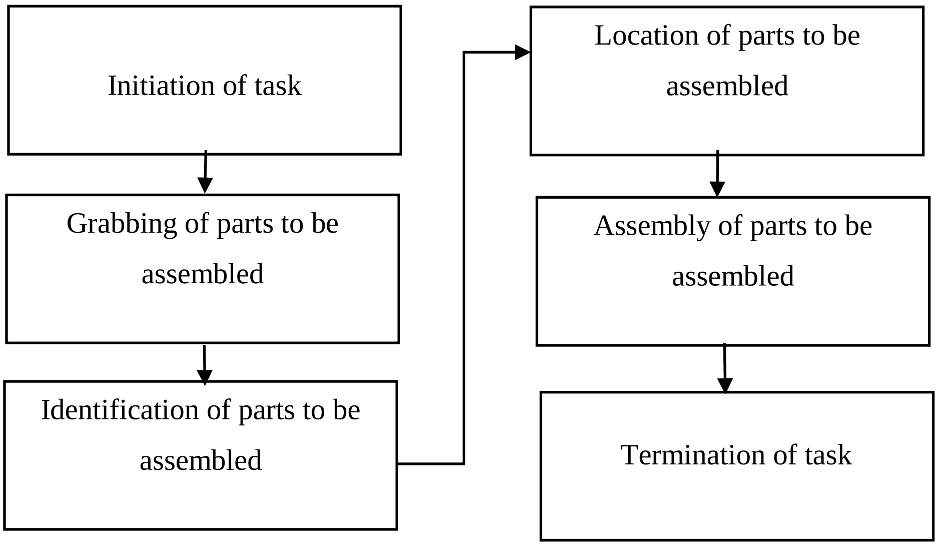


Figure 4. System Measurement and Assembly Process

3.1. Automatic Measurement of Microminiature Parts

Automatic measurement of microminiature parts is a process of microminiature parts identification, identification and positioning is the precondition of assembling the parts, and the accuracy of the two affects the assembly process directly and the quality of the product. The process of microminiature parts identification and positioning is the process of image preprocessing and image understanding after analysis. By filtering, sharpening, selection of image threshold, image binarization and feature extraction and other image processing and analysis method, we can pre-process the collected image of parts and obtain the information of characteristics of assembly parts. In precision adjustment stage, microminiature parts can accurately reflect its position by means of the image acquisition system and image processing system. Control system can realize precise positioning through location information of microminiature parts and then automatically adjust the moving direction and displacement of precision adjustment stage. Flow chart of image processing and analysis is shown in Figure 5.

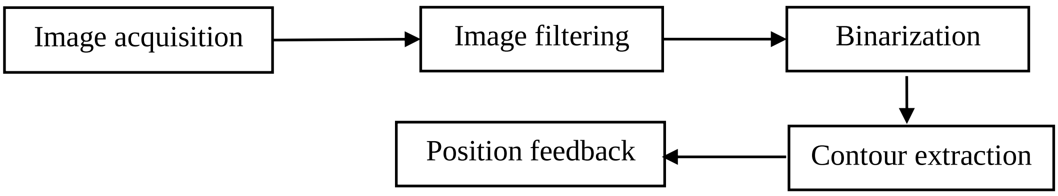


Figure 5. Image Processing and Analysis Process

In order to get the contours of the assembly parts, the original images of them are collected by visual measuring in different locations. The original image of the left side and the lower side for part1 is shown in Figure 6. As the process of collecting image will be affected by light and noise and other factors, it is required that these images should be preprocessed such as de-noising before edge detection and pattern recognition of images. We used MATLAB [3-4] to preprocess and analyze original images in this paper.Image preprocessing focuses on image enhancement, image smoothing and image sharpening. Firstly strengthen the contrast of the original image and transform the original image into gray, which is shown in Figure 7, and then use linear variation to adjust their gray value.

Gray-scale range of the original image f(x,y) is assumed as [a, b], the gradation range of the image g(x,y)after transformation is [c, d], then the expression of linear transformation is as follows:

$$g(x,y)=[(d-c)/\ (b-a)](f(x,y)-a)+c \tag{1}$$

Secondly, those images were processed by image smoothing and sharpening and we used a circular average filter for image smoothing.If S is the neighborhood set of pixels (x_0, y_0), (x,y) represents the elements of S, u(x,y)represents the gray value of the point(x,y), a(x,y)represents the weight of each point, the smoothing of (x_0, y_0) can be expressed as:

$$u^{'}(x_0,y_0)=\frac{1}{\sum\limits_{(x,y)\in S}a(x,y)}\left[\sum_{(x,y)\in S}a(x,y)u(x,y)\right] \tag{2}$$

Thirdly, those images were processed by image segmentation and edge detection. We used the method of global threshold function graythresh ()which uses Otsu threshold calculates global threshold of the image combined with im2bw () in MATLAB to turn grayscale images into binary images to achieve image segmentation. There are a lot of edge detection operators in MATLAB, but the Canny operator [5] has advantages of keeping the important edge and making sure that the position deviation between the real edge and the detected edge is minimum, so we used the Canny operator of automatic threshold for edge detection. The flow chart of the image processing and the edge extraction for part 1on the left is shown in Figure 8. The flow chart of the image processing and the edge extraction for part 1on the lower side is shown in Figure 9. The edge profile of part 1 is shown in Figure 10 . Finally, we used circular least-square iterative fitting location to realize the positioning of parts. Least squares curve fitting circle:

$$R^2=(x-A)^2+(y-B)^2 \tag{3}$$

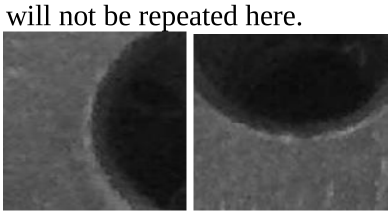
To make u=-2A,v=-2B, $w=A^2+B^2-R^2$,we can get another form of curve equation:

$$x^2+y^2+ux+vy+w=0 \tag{4}$$

Once we calculated the parameters u, v, w, we can obtain the parameter of circle radius. According to extreme value theorem on multiple samples collecting points, we can obtain the estimated fitting value of A, B, R.The least squares fitting circle diagram is shown in Figure11.The process of part 1 is the same as part 2, so it will not be repeated here.

the left side the lower side

Figure 6. Original Image of the Left Lower Side for Part1



the left side the lower side

Figure 7. Gray-Scale Image of the the Left and the Lower Side for Part1

Figure 8. Flow Chart of the Image Processing and Edge Extraction for Part 1 on the Left

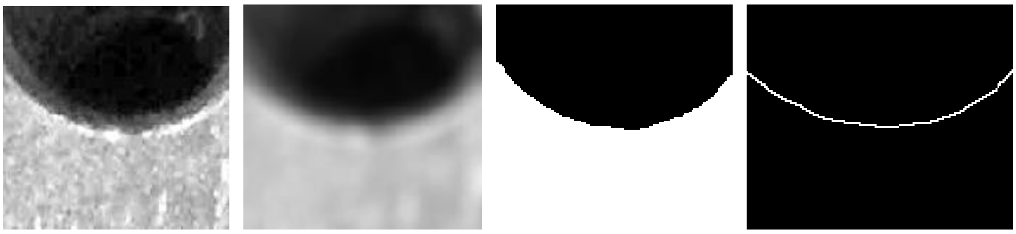


Figure 9 . Flow Chart of the Image Processing and Edge Extraction for Part1 on the Lower Side

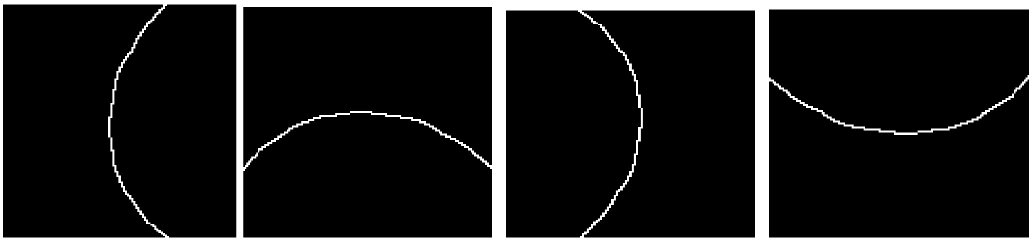


Figure 10. The Edge Profile of Part 1

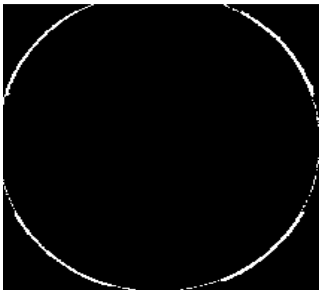


Figure 11. The Least Squares Fitting Circle Diagram

3.2. Precision Assembly of Microminiature Parts

Assembly process [6] of microminiature parts is the adjustment of displacement platform, alignment and assembly of parts. After the automatic measurement, positioning of the parts to be assembled will be realized. According to the difference of the positioning of parts to be assembled, system controls the movement of the displacement platform and gripping device of them. So that the parts would be aligned and finally the assembly of microminiature parts would be realized.

Pick up of microminiature parts is an important part of micro devices assembly. Generally speaking, clamping system of micro devices can be divided into clamp and a kind of micro vacuum adsorption, which can absorb and release microminiature parts by adjusting the pressure and vacuum suction diameter. As the pick device is required to control the clamp force strictly, the design and fabrication of it is a big project. And in order to avoid deformation or damage caused by picking up the microminiature parts, this paper adopts the method of micro vacuum adsorption to pick up the assembly parts. The assembly flow chart is shown in Figure 12.

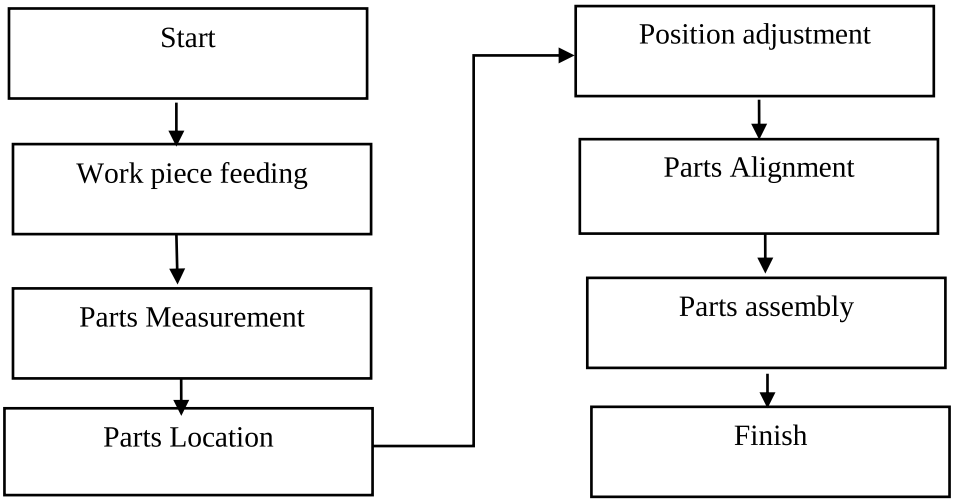


Figure 12. Assembly Flow Chart of Microminiature Parts

4. Conclusion

In view of assembly of the micro-and nanoscale parts , the detection method of stereo microscope combined with a high resolution CCD camera based on machine vision is proposed in this paper, and precision assembly system is developed as well. Once contour recognition and positioning of microminiature parts were achieved, the obtained shape and location parameters would feedback to the control system, hence the high precision assembly of microminiature parts was completed.

Acknowledgments

This work was supported by the National Nature Science Foundation of China(NSFC Grant No.51365021).

References

[1] P. Zhou and X. Li, "MATLAB digital image processing", Tsinghua University Press,Beijing, **(2012)**.
[2] C. Liu, "Automatic measurement and for miniature parts based on machine vision", Dalian university of technology, Dalian, **(2009)**.
[3] C. Zhu, "Machine vision based precise measurement and assembly for miniature components", Dalian university of technology,Dalian, **(2010)**.
[4] Z. Li, and M. Zhang, "Microhandling system based on machine vision", Optical instruments, vol. 31, no. 5, **(2009)**, pp. 56-61.
[5] H. Li, "Micro-assembly system based on machine vision", Beijing university of technology,Beijing, **(2006)**.
[6] L. Chen, Y. Li, Q. Li and L. Bai, "The completion on machine vision for microelement assembly system", Chinese journal of scientific instrument, vol. 22, no. 3, **(2001)**, pp. 257-258.

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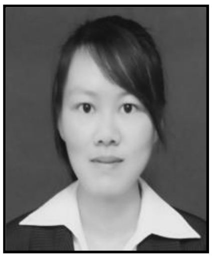

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