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Study on Algorithms of Graphic Element Recognition for Precise Vectorization of Industrial Computed Tomographic Image

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Abstract: Circle, line and circular arc are the common basic graphic elements in industrial computed tomography (ICT) image. The algorithm of recognizing such elements is the key to industrial CT image precise vectorization. An industrial CT image vectorization system has been studied, including different recognition methods for these elements. Firstly, based on facet model, the sub-pixel edge of an industrial CT image is extracted. Then, the circles are recognized by an improved algorithm based on probability of existence map, while the lines are recognized with the set intersection algorithm of fitting a straight line, and the circular arcs are recognized by the combination of the perpendicular bisector tracing algorithm and least squares function. Finally, the graphic element parameters are measured according to recognition results, and the drawing exchange file (DXF) is produced and transmitted into the computer aided design (CAD) system to be edited and consummated. The experimental results show that these methods are capable of recognizing graphic elements in industrial CT image with an excellent accuracy, besides, the absolute errors of circles are less than 0.1 mm, and the relative errors are less than 0.5%. It can satisfy the industrial CT vectorization requirements of higher precision, rapid speed and non-contact.

Keywords: Computed tomography, facet model, edge detection, vectorization.

1. INTRODUCTION

There has been remarkable research achievement in developing and applying computerized tomography (CT) technology for medical and industrial applications, particularly in the industrial area, such as aerospace, aviation, military, machinery and automobile. Industrial CT is not only effective to detect the inner construction and flaws of an object, but also necessary to nondestructively measure the size of workpiece [1, 2]. However, the two dimensional slice images acquired by the 3rd generation ICT device can't be edited in the existing computer aided design (CAD) system. And most industrial CT images are the workpieces' dislocation images, which have many geometrical elements, such as lines, circular arcs and circles. Several conventional vectorizaion methods, applied in engineering drawings and maps, come with disadvantages, including noise sensitivity, computational complexity and low accuracy. These shortcomings make it difficult to accurately measure the size of workpieces' inner construction. In order to overcome these problems, in this paper we investigate methods of industrial CT images precise vectorization.

Since the research of image vectorization started in the early 1970s, numerous approaches have been developed [3, 4]. Broadly, these algorithms can be divided into several groups: thinning algorithm, contour tracking, Hough Transform (HT), dynamic window method and global recognition algorithm. The main advantage of thinning algorithm is that it holds a better reservation of image topology information, and its processing data points are decreased. Nevertheless, it is sensitive to noise. As a solution of this problem, the contour tracking method is provided. Its processing rate is high, and the impact of the air bubble and burr defects on the vectorization effect is reduced. However, the recognition accuracy is low since the vector image is discontinuous. In terms of accuracy and robustness, the HT and its variants have been successfully used in image vectorization. These methods are robust against outlier and occlusion, but computationally expensive. Dynamic window vectorization algorithm was proposed as a relatively novel method. A major advantage of this method presents at its high recognition accuracy to crossing point. Unfortunately, the window is changing continually, so the robustness is not enough. With the vectorization technology improving, some researchers have presented global recognition method. In process of vectorization, the line width can be obtained. Meanwhile, the corresponding tracking mode is adopted for reducing the impact of line fracture and missing data. But the accuracy of crossing point should be further improved.

In view of the disadvantages of the current image vectorization methods, the key contribution of this paper is to investigate a vectorization system for industrial CT image. In this system, the sub-pixel edge of an industrial CT image is extracted based on facet model. Its execution time is reduced significantly by removing invalid data points. Then, the circles, lines and circular arcs are recognized respectively with the corresponding recognition algorithms. These algorithms improve recognition accuracy. Also, in the process of recognition, the obtained elements parameters are dynamically

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saved in the corresponding linked lists. Hence, the required computation storage space is much cheaper than the previous methods.

2. SYSTEM OVERVIEW

In the process of industrial CT image vectorization, it is critical to detect edges in the image which is an important stage as the quantity and quality of edge data will affect greatly the vectorization performance of the system. The sub-pixel edge contour is extracted by the edge detection algorithm based on facet model, after the pre-processing as Gaussian filter, binarization. For this contour, the recognition algorithms of graphic elements are implemented. Firstly, determine whether the contour is a circle by calculating the center's probability. If it is a circle, the improved fast algorithm of circle detection based on probability of existence map is utilized to recognize it. The obtained circle parameters by the least squares function (LSF) are saved in the circle chained list. Reversely, if it is not a circle, the contour curve is fitted into many short line segments by adopting the improved set intersection algorithm of fitting a straight line. Then, merge the short line segments into the long line segments. Finally, the perpendicular bisector tracing algorithm is adopted to find the long line segments which can be fitted into circular arcs. And the merged circular arcs' parameters are derived from the least squares function. These parameters are saved in the circular arc linked list. Another long line segments' parameters are saved in the line linked list. After recognizing these elements, their parameters are outputted for vector graph. The system architecture is summarized in Fig. (**1**).

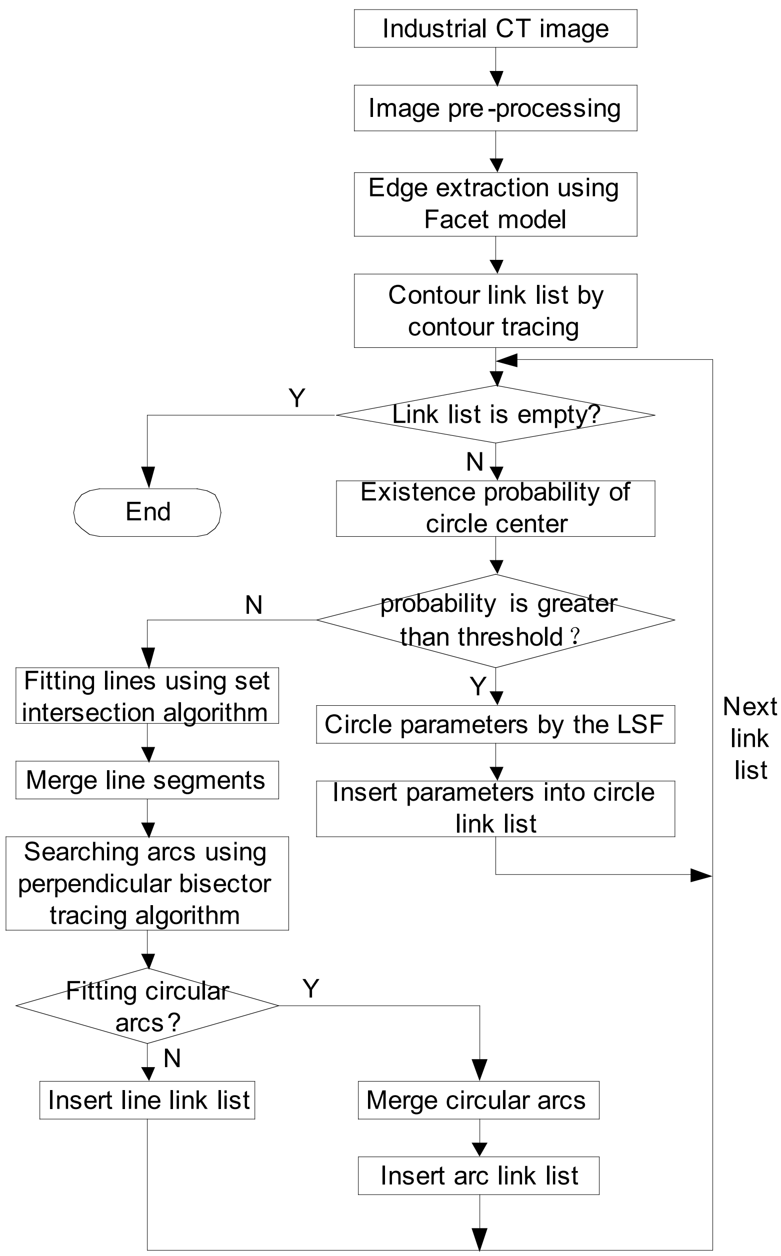

Fig. (1). Architecture of system.

setting the threshold is 0.7, our algorithms not only detect these four large circles correctly, but also fit them with good accuracy. The sizes of circles are marked in AutoCAD2008. Nevertheless, the small circles and slight contours can't be detected completely. If we decrease the threshold value appropriately, these small circles and slight contours will be detected. But the vectorization accuracy may be dropped.

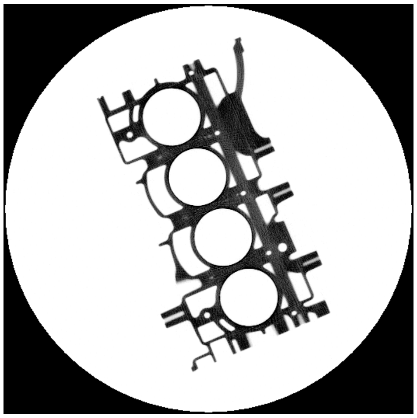

Fig. (8) (a). Industrial CT image of car engine.

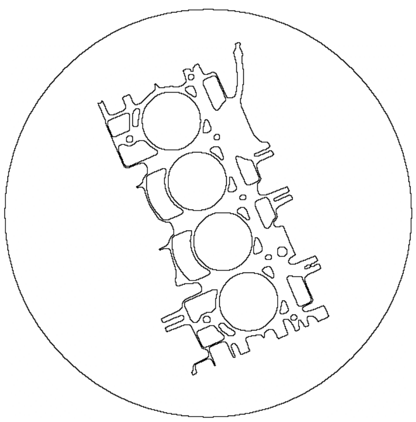

Fig. (8) (b). Sub-pixel edge image of car engine.

Fig. (8) (c). Vector graph of car engine.

Fig. (**9a**) shows an original industrial CT image of a gearbox cover. Unlike the previous industrial CT image of the car engine, this image has relative complex contours. In the top left corner are several small contours, which are difficult to be detected correctly. Despite this, its edge map is extracted completely and shown in Fig. (**9b**). Of particular interest is the vector graph of the gearbox cover in Fig. (**9c**) which evaluates our algorithms, and it is edited in AutoCAD2008. As shown in this picture, all circles are detected. Furthermore, several small circles are also detected and fitted correctly. Notice that the left isolated circle, which has the inner and outer concentric contours, is detected correctly. Also, the line contour can be fitted with ideal precision. However, Fig. (**9c**) also shows the limitation of our algorithms in the slight and complicated details of image. The circle with diameter of 16.55mm is nonexistent, it should not be found. And some contours are not with respect to the original contours ideally. For instance, the circular arc is represented by the irregular arc segments and curves. The following work will aim to resolve these problems.

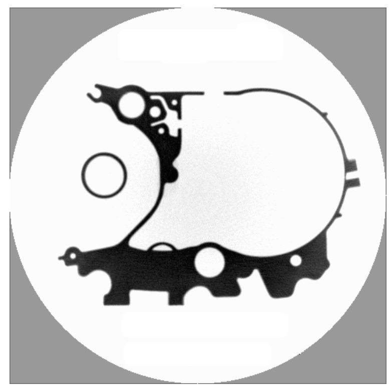

Fig. (9) (a). Industrial CT image of gear box cover.

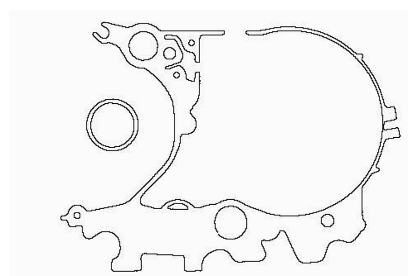

Fig. (9) (b). Industrial CT image of gear box cover.

Fig. (9) (c). Industrial CT image of gear box cover.

6. CONCLUSIONS

In this paper, an algorithm for sub-pixel edge detecting based on facet model is adopted for the pre-processed industrial CT image. For the obtained contour, we can calculate the parameters of circle using the improved fast algorithm based on probability of existence map. Then, a set intersection algorithm of fitting a straight line is applied for recognizing the line. Finally, use the perpendicular bisector tracing algorithm and the least squares function to recognize circular arc. Thus, a vectorization system of industrial CT image is designed, which provides the platform for our experiments.

Experimental results show indeed that our algorithms are capable of recognizing the circle, line and circular arc with an excellent accuracy. Furthermore, the vectorization performance for the whole image is preferable. It can satisfy the industrial CT image vectorization requirements of higher precision, rapid speed and non-contact. In the future, we will focus on extending this work by recognizing the relative complex graphic elements as ellipse, regular polygon.

ACKNOWLEDGMENTS

This research has been supported by the National High Technology Research and Development Program 863 (Project No. 2006AA04Z104). All industrial CT images are provided by ICT Research Center of Chongqing University.

REFERENCES

[1] F. L. Liu, G. F. Qiao and B. Zou, "Precise measurement of circles in industrial computed tomographic images", *Optics Precision Eng.*, vol. 17, no. 11, pp. 2842-2848, 2009.

[2] N. Y. Lee, S. H. Jung and J. B. Kim, "Evaluation of the measurement geometries and data processing algorithms", *Appl. Radiat. Isot.*, vol. 67, pp. 1441-1444, 2009.

[3] B. Cheng, S. S. Zhang and Y. F. Shi, "Research on Vectorization and Recognition for Engineering Drawings: a Survey", *J. Eng. Graph.*, vol. 29, no. 6, pp. 7-12, 2008.

[4] V. Nagasamy and N. A. Langrana, "Engineering drawing Processing and vectorization system", *Comput. Vis. Graph. Image Proc.*, vol. 49, no. 3, pp. 379-397, 1990.

[5] J. W. Tian, Y. Shu, D. P. Tian and Y. X. Huang, "Image sub-pixel feature location algorithm on vision measurement system", *Chin. J. Mech. Eng.*, vol. 42, no. 11, pp. 75-80, 2006.

[6] S. Zheng, J. W. Tian and J. Liu, "Efficient facet-based edge detection approach", *Opt. Eng.*, vol. 44, no. 4, pp. 1-10, 1990.

[7] Y. C. Zhang, H. M. Wang, Z. Z. Liang, M. Tan, W. B. Ye and B. Lian, "Existence Probability Map Based Circle Detection Method", *Comput. Eng. Appl.*, no. 29, pp. 49-51, 2006.

[8] F. L. Liu and G. F. Qiao, "A Fast Algorithm of Circle Detection for Industrial CT Images Based on Probability of Existence", *China Mech. Eng.*, vol. 19, no. 19, pp. 2335-2339, 2008.

[9] Q. H. Li, D. Q. Wang and Z. Y. Chen, "Research on Image Vectorization Methods and Algorithms", *Appl. Res. Comput.*, no. 6, pp. 9-12, 1995.

[10] H. Y. Guan, J. Q. Zhang, Q. Hu and L. Zhong, "Line Extraction of industrial parts based on least square template matching," *Proc. - Int. Congr. Image and Signal Processing (CISP 08)*, IEEE Press, July 2008, pp. 696-700.

[11] D. Dori and W. Y. Liu, "Stepwise Recovery of Arc Segmentation in Complex Line Environment", *Int. J. Doc. Anal. Recog.*, vol. 1, no. 1, pp. 62-71, 1998.

Received: November 26, 2010 Revised: December 29, 2010 Accepted: January 07, 2011