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Precise Object Detection Using Local Feature for Robot Manipulator

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Abstract – It is difficult to apply object recognition technology to manufacturing industry because the intrinsic characteristics of an object is easily influenced by the surrounding environment such as lighting condition, background complexity and object shape.

This paper proposes a precise object detection method for assembling components by more stable feature extraction. To accomplish it, two images are captured by fine-tuning exposure time for the purpose of complementation of features. Adaptive binarization and differential of Gaussian methods are applied to extracting edge information from each image. In the next step, primary features such as contour lines are extracted from the object using the Fast Hough Transform and candidate lines are selected to become geometric conditions of the object. The precise object region is detected by shape analysis using the four vertices computed by the candidate lines. In addition, the internal features of the object are employed to increase the precision of object detection. As a result, the proposed method improved the accuracy of object detection so that it can be useful in the visual servoing using the robot manipulator.

Keywords – Object detection, Local feature extraction, DoG, Adaptive binarization, Robot manipulator.

1. Introduction

The robot manipulator is usually used to assemble a vehicle through a simple repetitive process without vision system. The position and angle of the component must be constantly positioned to perform the assembly process. This manufacturing process automation is currently being applied to electronic and electric industries. In applying this system to the electronics and electric industries the main problem is a lack of accuracy of object detection. It is hard to pick up components and assemble them because the parts, either electronics or electric, are complex in shape and tiny. With these reasons, object detection accuracy is the most critical element to apply the automatic manufacturing robot system to electronic and electric industries.

In particular, there is a growing demand for the automation manufacturing plant using object recognition to be applied to the assembly and packaging fields. In order to assemble and package components, the information such as angle, position and center point coming at random should be extracted in precision. In general, however, the environment in all manufacturing industries is not the same. It is not easy to detect the object region according to the lighting effect, the material or shape of the target object because the lighting condition can vary based on the work site and object itself.

There are several edge extraction techniques such as Sobel, Canny, Gaussian methods [2, 3], however, the outline information of object region cannot be extracted precisely because lighting condition leads to distorted contrast and causes loss of features in the object region.

In the paper, we suggest the precise object detection method using local feature and hierarchical feature analysis. We selected adaptive binarization and differential of Gaussian technologies because these are less affected by lighting and most fittable on our work. By using two captured images with above both methods in each image, features are extracted clearly. Based on the contour lines, the object region is detected by using Fast Hough Transform, and the features in the object area are analyzed to make sure if objects are detected properly. In other words, after object outlines are formed by using internal features and compared with previous candidate lines, the closest candidates are selected. We can verify a more accurate object domain with this method through experiments.

2. Object Detection System

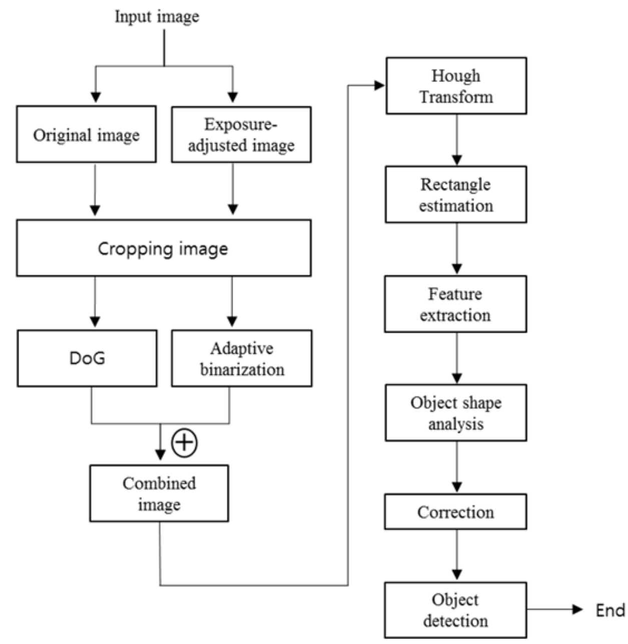


Fig. 1. Flow chart of proposed method

The proposed method is to detect the target object precisely for robot manipulator in electronic and electric fields.

The first step in detecting the target object is to extract edge information. Existing techniques such as Sobel, Canny, Gaussian, and adaptive binarization method indicated that the features in the target object could vanish due to environment and lighting conditions. To solve the problem, we combined two captured images to apply adaptive binarization and differential of Gaussian method to extract features and to solve the vanishing problem.

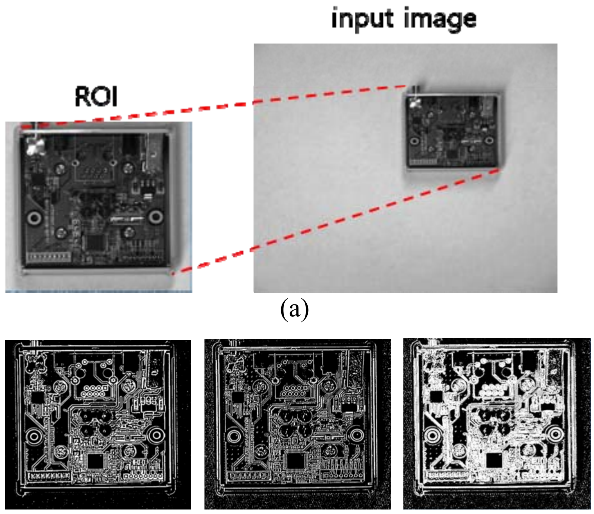


Fig. 2. (a) Crop image from manipulator end-effector (b) Adaptive binarization (c) DoG (d) Image combined (b) and (c)

Next, the contours were extracted from the edge information obtained in the previous step. We used Fast Hough Transform [4, 5] to detect lines based on the contours because it is fast and powerful for line detection.

$$\rho = x\cos\theta + y\sin\theta, \qquad \text{(1)}$$

Let $H_1 = (\rho_1, \theta_1)$, $H_2 = (\rho_2, \theta_2)$, ... , $H_n = (\rho_n, \theta_n)$ denote values in Hough space. Randomly select H_i, H_j initially and scan other lines which are parallel and have approximately the same length. After that select a straight line that is orthogonal to H_i and repeat the previous work to satisfy the following conditions.

$$\Delta\theta = |\theta_i - \theta_j| \le T_\theta \qquad \text{(2)}$$

$$\Delta\rho = |\rho_i + \rho_j| \le T_\rho \qquad \text{(3)}$$

$$|L_i - L_j| \le T_L \frac{|L_i + L_j|}{2}, \qquad \text{(4)}$$

T_θ is an angular threshold to determine whether H_i and H_j are parallel lines. T_ρ is a distance threshold and T_L is a normalized threshold to determine whether two lines are approximately the same length.

Then search all of the points of intersection. The points are gathered around the edges of the rectangle.

After clustering them into 4 regions, select the innermost points in each clustered region. Approximately estimate the rectangle with selected 4 points.

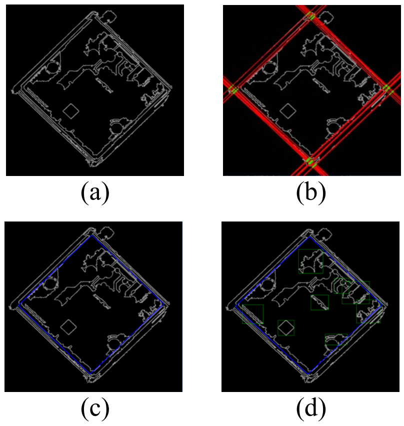


Fig. 3. (a) Contour extraction (b) Line detection using Fast Hough Transform and clustering points of intersection (c) Rectangle estimation (d) Bounding for contour analysis

Finally, for the sake of precision, we extracted features in the object region for object shape analysis. In this method, contour analysis [6] was used to analyze the object shape. The contour is composed of complex numbers from the contour analysis. On a contour, the starting point is fixed and the contour is scanned. We should do equalizing work, the process to be uniform all of the contours' length for searching and comparing contours.

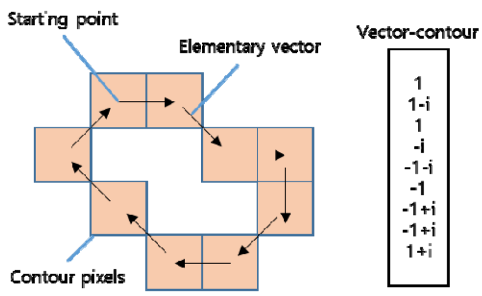


Fig. 4. Object shape analysis concept

Afterwards the distance between the object region and contours found by the contour analysis is compared to verify whether the object detection is correct. If the rate is incorrect over the specific threshold which is gained through experiment, the contours are used to detect the object area and select the closest line compared to the previous candidates obtained from Fast Hough Transform

3. EXPERIMENTAL RESULTS

The experiment environment is as follows. The machine vision camera used is Toshiba's Teli DU657M. We are equipped with conveyor belt and manipulator UR3 from Universal Robots for future work as shown in Figure 5.

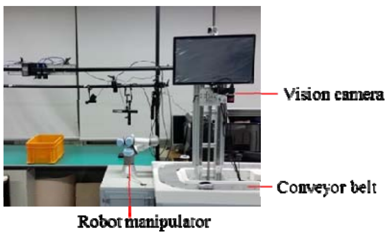


Fig. 5. Experiment environment for visual servoing

Our experiment for object region detection was conducted on both synthetic and natural images. The images used in our experiment were 288(72 images rotated 5 degrees from 0 to 360, 2 different background and exposure time: 72 * 4).

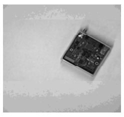
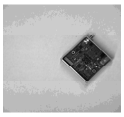
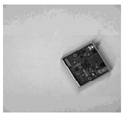
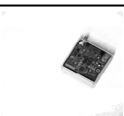
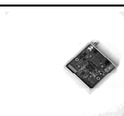
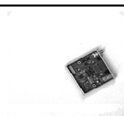
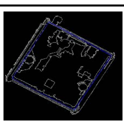
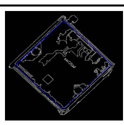
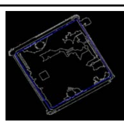
Rotated angle	30°	45°	60°
Original image			
Exposure-adjusted image			
Object detection			

Fig. 6. Sample Database and Processed Images

The experiment proceeded under natural light conditions and the shape of the target object is assumed to be a rectangle.

When we detected the object region without object shape analysis, the accuracy of object detection was 83.3%. The reason for the high error rate in object detection was influenced by Lighting and environment condition.

After that we applied the object shape analysis to the test. The accuracy of object detection was 96.875%(279 images). Based on contour rotation and location information, the rectangle was estimated and compared with the previous detected object region. If the detected object region was incorrect because of distance or angular problem, we revised the rectangle by comparing distance between the detected object regions by analyzing contours and previous candidate regions by Fast Hough Transform and selected the most closely matching region. But there was a 3.125%(9 images) of object detection error due to vanished features in the rectangle. As a result, detection rate improved though it still had the feature extraction problem.

3. CONCLUSION AND FUTURE WORK

This paper proposes a method to detect a precise target object area. Our approach aims to detect the object part without failure. In combining two binarization techniques, we can extract more features and analyze contours for stronger edge extraction.

Our ultimate goal is to recognize the accurate target object, so that we can assemble electronic components. This research is part of the ongoing process. Therefore, the future work is to improve the accuracy and add a recognition system to this algorithm. In order to apply it to automatic manufacturing industries, research in the assembly and packing field has been very active. Throughout research, accuracy was the most important factor. We were seeking a more accurate algorithm.

Acknowledgement

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References

[1] Tomas Lozano-Perez, Automatic Planning of Manipulator Transfer Movements, IEEE Transactions on Systems, Man, and Cybernetics, Vol. 11, Issue: 10, Page(s): 681 - 698, Oct. 1981.

[2] Larry S. Davis, "A survey of edge detection techniques", Computer Graphics and Image Processing, Vol. 4, Issue 3, Pages 248-270, Mar. 2008.

[3] M. Basu, Gaussian-based edge-detection methods-a survey, Computer Graphics and Image Processing, Vol. 32, Issue: 3, Page(s): 252 – 260, Aug. 2002.

[4] Richard O. Duda and Peter E. Hart, Use of the Hough transformation to detect lines and curves in pictures, Communications of the ACM, Vol. 15, Issue 1, Jan. 1972.

[5] Hungwen Li., Mark A Lavin., Ronald J Le Master, "Fast Hough transform: A hierarchical approach", Computer Vision, Graphics, and Image Processing, Vol. 36, Issues 2–3, Page(s) 139-161, 1986.

[6] Torgashov, P. (2014). Contour analysis for image recognition in c#.

[7] Dong-Ho Lee, An Edge-Based Adaptive Method for Removing High-Density Impulsive Noise from an Image While Preserving Edges, ETRI Journal, Vol. 34, no. 4, Aug. 2012, pp. 564-571.