Visual-servo Control of 4-DOF Robot Manipulator for Sorting Moving objects

Longtan Wang
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu
Busan, 609-735, Republic of Korea

Seon-Woo Kim
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu
Busan, 609-735, Republic of Korea

Hyun-Wook Ha
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu
Busan, 609-735, Republic of Korea

Jang-Myung Lee
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu
Busan, 609-735, Republic of Korea

E-mail: longtan7379@pusan.ac.kr, seonwoo7379@pusan.ac.kr, hyunuk.ha@gmail.com, jmlee@pusan.ac.kr
www.pusan.ac.kr

Abstract

This paper considers the problem of estimating position and determining class of objects on the moving conveyor belt. A 2D camera is utilized to capture the image of moving objects. The control system directly integrates visual data into the servoing process. Objects are recognized by firstly removing the background using adaptive thresholding algorithm, then find objects outer contours and determine the size and shape by topological structure analysis tracking boards, then Rotating calipers algorithm is adopted to estimate the centroid position and orientation of the objects. Finally control the robot manipulator pick different moving objects to different position. The proposed system is able to control the robot so that it can approach the desired position and grab the specific object.

Keywords: Robot; Adaptive thresholding; Topological Structure Analysis; Rotating calipers

1. Introduction

Sorting objects on the moving conveyor belt by robot is an essential part in a production line [1]. Despite many methods to sort the objects, vision based robot may be one of the most favored one in terms of the cost and efficiency.

However different kinds of objects holds different features, classify them often needs different algorithms. For a sorting system, if the sorting objects changes, the segmentation algorithm always need be altered. The past research mostly devoted to segment and recognize objects by surface features. For example, when sorting the transparent or reflective objects, the surface features changes as the illumination changes, typical vision algorithms first extract the features of the surface and then compare it with the database to determine the class of it. So recognizing them by using feature related algorithms becomes a difficult job.

In this paper a sorting system with objects holds different size is addressed. As mentioned above, the surface appearance of the object is easily affected by the illumination, which makes it difficult to extract features and thus segment them becomes impossible. Instead of segment them by surface feature, we propose a way to segment and recognize objects by its size.

2. Develop Environment

As shown in Fig. 1. the robot system consists of a 4-DOF manipulator and a finger like gripper, a tablet PC, a conveyor belt, a Basler industry camera with ring light, which is installed on top of conveyor belt and in front of robot operation area.

Fig. 1. Experiment environment

As shown in Fig. 2. once the object appears in the view of the camera. The vision system will begin to find all the outer contours and thus get each shape. This way we will get the size of each object in the view. After that, the system will continue to compute its current position and orientation. According to information got from vision system, the PC will figure out a suitable strategy of motion planning and control the robot sorting objects.

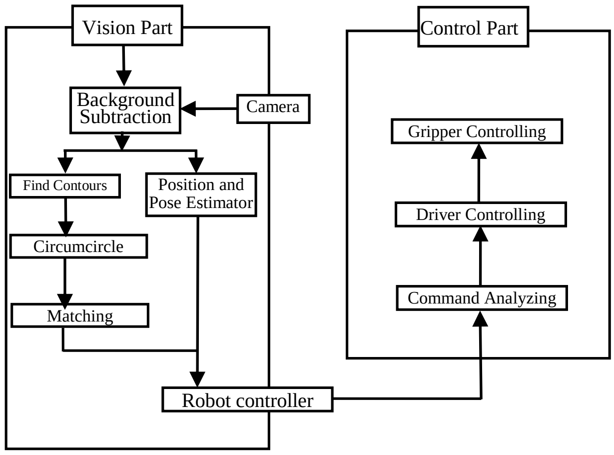


Fig. 2. System architecture

3. System Operation

The system Operation is make up of several main steps, each step is an essential part.

3.1. *Background Subtraction*

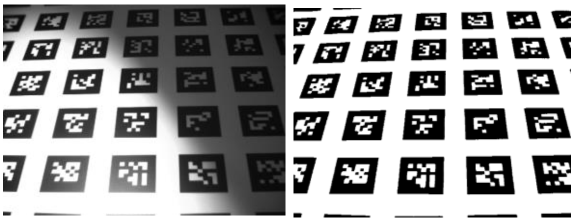
Background subtraction is a very important procedure for of many vision based applications. Background model is a relatively static model and its modeling is at heart of any background subtraction algorithm. Due to its flat and monochrome surface, consider the conveyor belt as a time invariant background, and it is sensitive to the illumination. Apply the background subtraction process in order to eliminate noise and correct uneven illumination. Also can determine whether the objects have come in view of camera. If so, the vision system will save the image for further processing. If not, the vision system will continue monitoring the conveyor belt.

Adaptive thresholding [2] is a form of thresholding that takes into account spatial variations in illumination. Due to the video stream, we have to maintain real-time performance, which means the less iteration times the better. A simple and fast adaptive thresholding technique is adopted. The first step is to get the integral image.

$$I(x,y) = f(x,y)+I(x-1,y)+I(x,y-1)-I(x-1,y-1) \qquad (1)$$

Eq. (1) shows the process of integral image. To compute the integral image, we store at each location, I(x,y), the sum of all f (x,y) terms to the left and above the pixel (x,y). This is accomplished in linear time using the following equation for each pixel (taking into account the border cases.

Fig. 3. shows adaptive thresholding effects, which decrease the influence of uneven illumination.



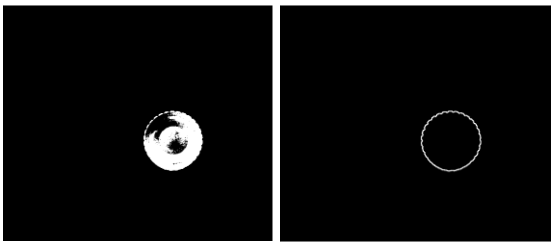
(a) (b)

Fig. 3. (a) Original image, (b) After adaptive thresholding

3.2. *Find Contours*

After removing background, we need to find the contours by using topological structural analysis [3]. This step is the used for finding all the objects appeared in view of the camera. Each outer contour represents an object.

Find the contours by border following using topological structural analysis. Since the outer borders and the hole borders have a one-to-one correspondence to the connected components of l-pixels and to the holes, respectively, the topological structural analysis by



(a) (b)

Fig. 4. (a) Origin binary image; (b) Contour of object

border following yields a representation of a binary image, from which one can extract some sort of features without reconstructing the image. As shown in Fig. 4. The shape can be recognized

3.3. *Position and Orientation Estimation*

In order to get the centroid position of an object, what we need we have to know firstly is its shape. Assume that the centroid is the center of its minimum bounding rectangle(NBR), which means this rotated rectangle is the smallest one that enclosing the object in the image. While the pose is represented by the angle this rectangle has rotated. What we need is to find its minimum bounding rectangle.

We adopt Rotating calipers algorithm [4] which is a well-known algorithm for finding the minimum rectangle [5]. As shown in Fig. 5.

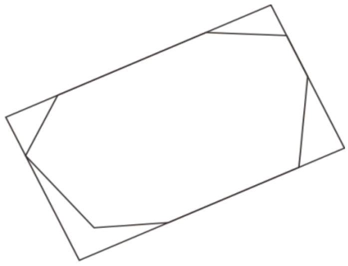


Fig. 5. Minimum bounding rectangle

3.4. *Motion Planning and Control*

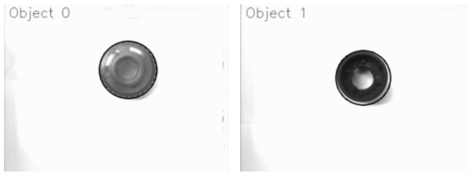
The control strategy is assigned based on information got from vision part. The manipulator and gripper will work together to move the object to specified area [6][7].

4. Experiment Result

We design an experiment which will test the result of the recognizing effects and real-time performance.

In this experiment, different kinds of objects are placed in order continually. The robot will recognize their kinds and place different kinds of objects to different places.

In this experiment the camera continues capturing gray-level image at 500*690 resolution. The camera capture images in real-time and each frame of the image will be checked to find and recognizing the objects. Then the robot manipulator will grab the object and place each to a specified area. Fig. 6. shows the experiment process. Different kind of object will be recognized.



(a) (b)

(c) (d)

Fig. 6. Experiment results. (a) Object 0; (b) Object 1; (c) Object 3; (d) Object 4

5. Conclusion

This paper proposes a design of robust recognizing and grasping objects in real time. High robustness has been demonstrated in recognizing featureless objects. The adaptive thresholding algorithm and topological structure analysis are used in recognizing objects, while rotating calipers algorithm is applied to estimate the centroid position and orientation of the objects. A path planning scheme is thus yielded based on the information gotten from vision system. Experimental results illustrate the good efficiency performance.

Acknowledgements

This research was supported by the MOTIE (Ministry of Trade, Industry & Energy), Korea, under the Industry Convergence Liaison Robotics Creative Graduates Education Program supervised by the KIAT (N0001126).

This work was supported by the National Research Foundation of Korea(NRF) Grant funded by the Korean Government(MSIP) (NRF-2013R1A1A2021174).

References

1. Ik Sang Shin, et al. "Conveyor visual tracking using robot vision." *Proceedings of 2006 Florida Conference on Recent Advances in Robotics, (2006) 1-5.*
2. Derek Bradley, Gerhard Roth. "Adaptive thresholding using the integral image." *Journal of graphics, gpu, and game tools 12.2 (2007) 13-21.*
3. Suzuki, Satoshi. "Topological structural analysis of digitized binary images by border following." *Computer Vision, Graphics, and Image Processing 30.1 (1985) 32-46.*
4. Toussaint, Godfried T. "Solving geometric problems with the rotating calipers." *Proc. IEEE Melecon, Vol. 83, (1983).*
5. D. Chaudhuri, A. Samal. "A simple method for fitting of bounding rectangle to closed regions." *Pattern recognition 40.7 (2007) 1981-1989.*
6. Hyun Woo Kim, Hu Chen, Jang Myung Lee, "Path planning of 5-DOF manipulator." *Advanced Intelligent Mechatronics (AIM), (2014) 877-881.*
7. Dirk Buchholz, et al. "Combining visual and inertial features for efficient grasping and bin-picking." *Robotics and Automation (ICRA), 2014 IEEE International Conference on. IEEE, (2014).*