A Robust Recognition Method for Occlusion of Mini Tomatoes based on Hue Information and Shape of Edge

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ABSTRACT

In this paper, we propose a robust recognition method for occlusion of mini tomatoes based on hue information and shape of edge. This method is used for a managing system using robots for hydroponic that we have proposed. In this system, robots need to detect mini tomatoes to manage farmlands. In a lot of cases, mini tomatoes are covered partially behind its leaf stems or its other fruits. Thence, the system needs a mini tomato recognition method in the situations including occlusion. Firstly, this method detects red areas using hue information from a source image. Secondly, the method detects contours from the areas using contour tracking. Finally, the method judges whether contours are mini tomatoes or not using the curvature. Experimental results showed that recognition rate of this method was 78.8%. Therefore, we consider that the proposed method is appropriate for mini tomato recognition in the situations including occlusion.

KEYWORDS

Hydroponic, Object recognition, Contour tracking, Curvature, Hue Information

1 INTRODUCTION

In recent years, hydroponic that raises vegetables by not using soils has attracted attention in agriculture [1]. In addition that hydroponic is able to raise large amount of vegetables in the narrow space of the building, it doesn't make injury by continuous cropping and weather cannot harm raising crops as merits [2]. As the feature of crops suited to hydroponic, it doesn't take times and has strong disease resistance. In these crops, there are mini tomatoes that have much demand in the market, expensive price, and can attain stable crop of yield.

Since, as a method to make use of hydroponic that has many advantages, we propose an automated hydroponic system using robots to control a lot of farmland efficiently. However, it is desirable that a savvy farmer works to make good farm crops. Therefore, we propose a managing system for hydroponic that one savvy farmer controls the system and robots do hydroponic in many farmlands. There are two modes in this system.

- Auto control mode: robots check growing state of farm crops automatically.
- Remote control mode: a farmer works from the distant place using robots.

When robots check growing state of mini tomatoes in remote control mode, the robots have to recognize mini tomatoes.

2 THE CONVENTIONAL METHOD

There is a method of the object recognition called the template matching [3]-[4]. However, the template matching is not good for the system because it is valuable in illumination change. Therefore, we proposed a method to detect mini tomatoes using hue information that is strong for illumination change and its shape. This method calculates the roundness [5] of candidate areas to detect because mini tomato's shape is almost circle. The roundness is calculated using the following equation.

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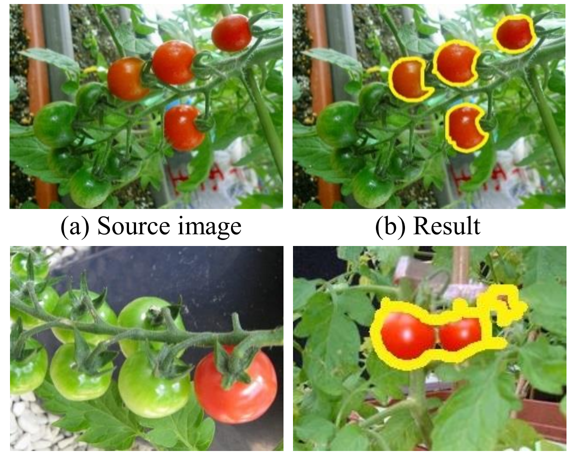
$$R = \frac{4\pi S}{L^2} \qquad (1)$$

S is a candidate area that is detected using hue information. L is a perimeter of the candidate area. Fig. 1 (b) shows the result that detected mini tomatoes using this method. Fig. 1 (a) shows a source image. Green tomatoes are not included in objects of the detection. This method can detect 83% mini tomatoes from source images. However, this method cannot detect mini tomatoes which are covered by its calyx shown in Fig. 1 (c). This method also cannot detect mini tomatoes which are too near other one shown in Fig. 1 (d). Mini tomatoes are often covered partially behind its leaf stems or its other fruits because mini tomatoes produce many fruits at one time. It is difficult to detect individually each mini tomato from image of mini tomatoes overlapping each other because candidate areas are not detected correctly.



(a) Source image (b) Result

(c) Case of failure 1 (d) Case of failure 2

Fig. 1 Results of a method using hue information and roundness

Fig. 2 Source image

Fig. 3 Candidate areas

3 THE PROPOSED METHOD

3.1 Outline

We propose a robust recognition method for occlusion of mini tomatoes based on hue information and shape of edge. A purpose of our method is to detect mini tomatoes correctly even mini tomatoes are covered behind leaf stem or other fruits from source images. Firstly, this method detects candidate areas using hue information. Secondly, this method detects edge information from candidate areas and detects contours individually using contour tracking. Candidate areas detected using hue information may contain areas that are not mini tomatoes, since this method calculates the curvature of contours. When the curvature stays constant in a certain interval, we recognize that candidate areas as mini tomatoes.

3.2 Detection of Candidate Arias Using Hue Information

This method makes mask images to detect candidate areas from source images. Firstly, this method converts RGB color images to HSV color images. Secondly, the method converts source images to binary images. A white pixel in a binary image expresses that a hue value of a pixel in source image is parameter of red. A black pixel in binary image expresses that a hue value of a pixel in the source image is not parameter of red. This method executes morphological operation and fills space of highlight with black because there are many noises in images. These processes accomplish mask images. This method applies mask images to source images to detect candidate areas (Fig. 3).

3.3 Preparation for Contour Tracking

This method detects edges from candidate areas to execute contour tracking that can detect contours individually. Additionally it is necessary to change width of edge to 1 pixel and to connect broken lines for contour tracking.

Firstly this method converts images of candidate areas to images expressed only value information because it is easy to detect edges by using Canny algorithm. Fig. 4 shows detected edges. Secondly this method executes morphological operation processes to connect broken lines because there are many layers of edges. The edges after morphological operation processes need to be thinned because it is too wide. Therefore this method executes thinning of edges. An image after thinning is shown in Fig. 5.

Next step is to search end points of broken lines and connect two end points by drawing lines or erase lines. Firstly this method scans an image from upper left to search a pixel that is part of edge (white pixel). A white pixel is judged as an end point if there is only white pixel in 8-neighbors around it. After that, this method restarts scanning and storing all end points. Secondly, this method calculates the distance between two points chosen in stored end points. If the distance is short, the method draws line of 1 pixel of width between them. If the distance is long, this method erases a line starting at end point. There are two cases to erase line.

- Between an end point and an intersection point
- Between an end point and another end point

Firstly this method choses an end point as an attention point. Then, the attention point repeats moving to a white pixel in 8-neighbors around it. When an attention point moves, erase a point before move (changed to black pixel). When an attention point does not have a white pixel in 8-neighbors, the processing ends because it is end point. When an attention point has over two white pixels in 8-neighbors, processing ends because it is an intersection point.

These processing get seamless edges of 1 pixel of width (Fig. 6).

3.4 Contour Tracking

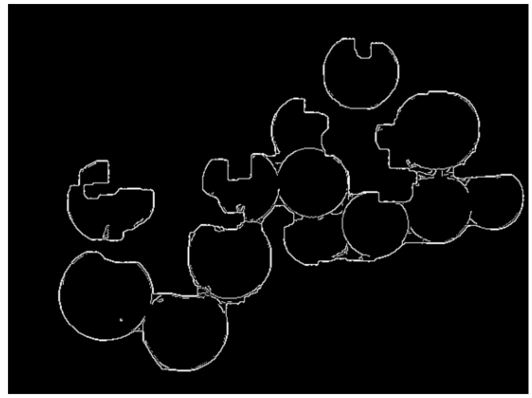


Fig. 4 Detected edges

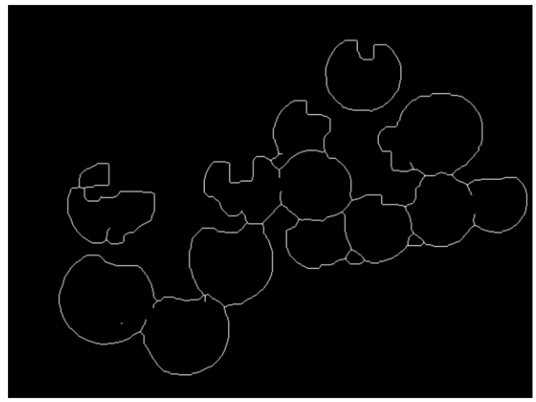


Fig. 5 Thinned edges

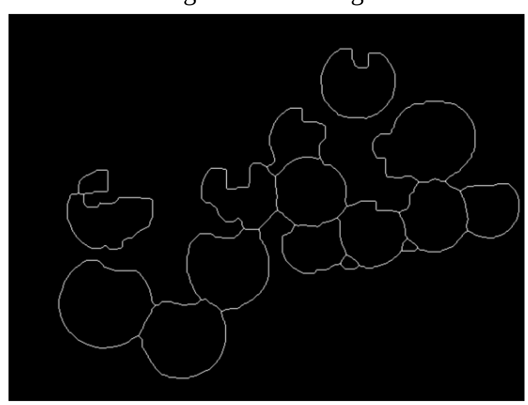


Fig. 6 Connected edges

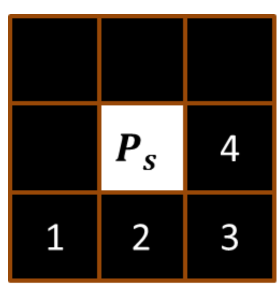


Fig. 7 Numerical order of searching white pixel around starting point

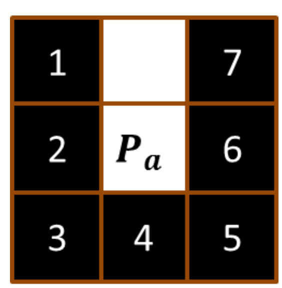


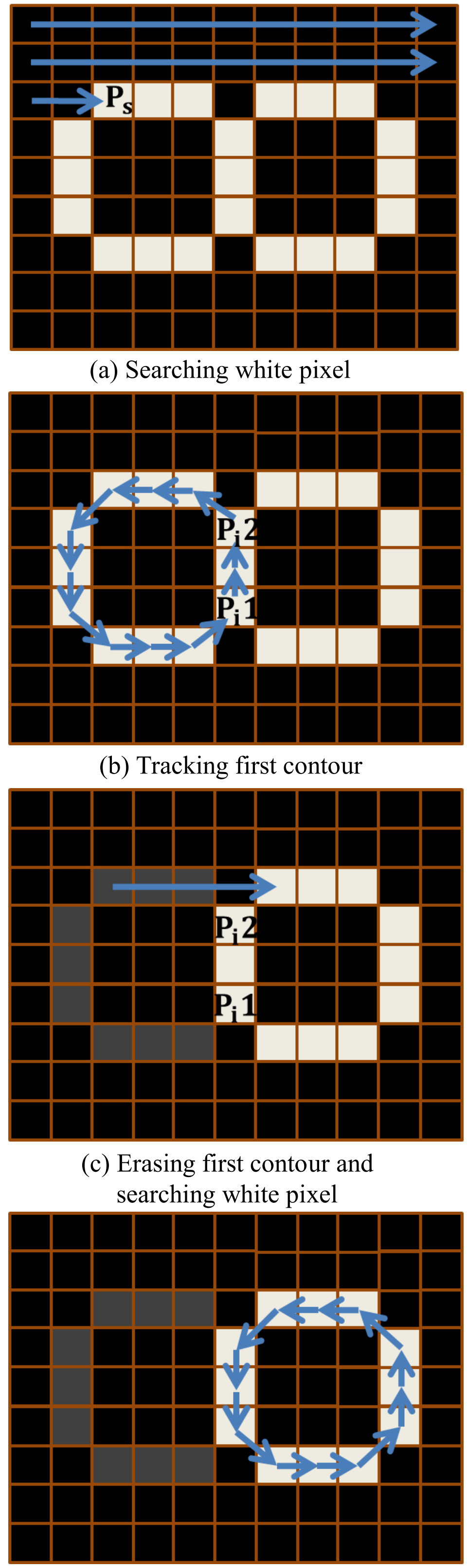
Fig. 8 Numerical order of searching white pixel around attention point

This method detects contours individually from an edge image using contour tracking. A flow of contour tracking is shown in Fig. 9.

Firstly this method scans images from upper left to search a white pixel. If a white pixel is found, the method stops scanning and recognizes that point as a starting point (Fig. 9 (a)). Secondly this method searches a white pixel in 4-neighbors of the starting point in numerical order shown in Fig. 7. If a white pixel is found, an attention point moves to it. After that, this method searches a white pixel in 8-neighbors around the attention point that does not include point before move counterclockwise. The attention point moves to the found white pixel. The attention point continues to move until it returns the starting point (Fig.9 (b)). If some white pixels exist in 8-neighbors around an attention point, this method stores the attention point as an intersection point and the attention point moves to a white pixel that is found lastly. When the attention point returns to the starting point, this method erases a contour. If there is not intersection point in a contour, this method erases all points of a contour. If there is a one intersection point, this method erases points of a contour that do not include the intersection point (Fig.9 (c)). If there are two and over intersection points, this method erases points of a contour between a first intersection point and a final intersection point. After that, this method restarts scanning and these processing to detect all contours (Fig.9 (d)).

3.5 Judging of Mini Tomatoes Using the Curvature

Candidate areas detected by hue information may include areas that are not mini tomatoes. Then this method judges whether each contours are mini tomatoes or not using the curvature [6]. The curvature stays constant in an interval that is not hidden on something because mini tomato's shape is almost circle. This method



(a) Searching white pixel
(b) Tracking first contour
(c) Erasing first contour and searching white pixel
(d) Tracking second contour

Fig. 9 Flow of contour tracking

calculates the curvature using the following equations.

$$\frac{1}{R} = \frac{\Delta\theta}{\Delta s} \tag{2}$$

$$\Delta s = \sqrt{(x_b - x_a)^2 + (y_b - y_a)^2} \tag{3}$$

$$\Delta\theta = \frac{\frac{y_c - y_b}{x_c - x_b} - \frac{y_b - y_a}{x_b - x_a}}{1 + \frac{(y_c - y_b)(y_b - y_a)}{(x_c - x_b)(x_b - x_a)}} \tag{4}$$

This method calculates the curvature using these contour points A, B, and C. The curvature is the inverse of the curvature radius. $\Delta\theta$ is defined as the angle between two vectors. Δs is defined as the distance between two points. Point A is first point of a contour. Point B is an after 15 points from point A. Point C is an after 15 points from point B. This method calculates the curvature and judges whether a curvature value is included in value of mini tomato. The method moves point A to next contour point. The method repeats these processing on all contour points. If the curvature value stays constant in an interval, the method judges a contour as a mini tomato.

4 EXPERIMENT

In this experiment, we tested the performance of the proposed method using 10 source images. Targets of recognition are mini tomatoes that its surface can be seen more than a quarter. Green or yellow tomatoes are not included in targets.

Here are parameters used in the method.

- Hue value

This method sets hue value between 0 and 18 or between 170 and 180 to detect red areas.

- Distance between end points to connect

To connect broken lines, the method draws lines between end points if these distance is lower than 30.

- Number of contour points

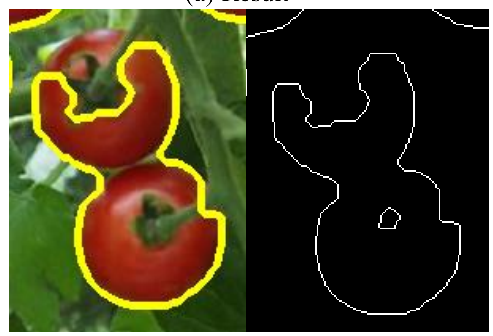
A contour that has lower than 100 points is not stored as a candidate area.

- Interval of points used in the curvature

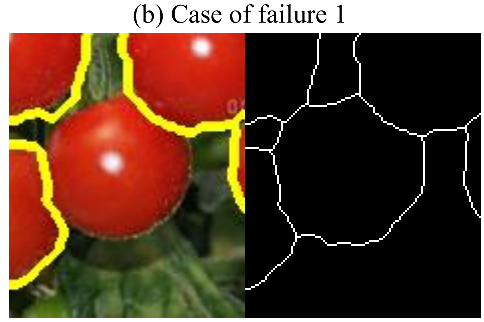
A distance of three points used in the curvature is 15.

- Curvature value of mini tomato

(a) Result



(b) Case of failure 1



(c) Case of failure 2

Fig. 10 Results of proposed method

Curvature value of mini tomato is between -0.400 and -0.100.

- Judgment of mini tomatoes using the curvature

If there are more than 30 points that is value of a mini tomato among 40 contour points, the method judges the contour as a mini tomato.

A result of recognition using the method, it is able to recognize 78.8% mini tomatoes from 10 source images (Fig.10 (a)). This method is not able to detect areas that boundary edges are not detected correctly (Fig.10 (b)) and areas that have transformed contours by morphological operation processes or thinning (Fig.10 (c)).

5 CONCLUSION

In this paper, we proposed a robust recognition method for occlusion of mini tomatoes based on hue information and shape of edge. The method is able to recognize 78.8% mini tomatoes from 10 images. We consider that the method is useful for the managing system for hydroponic. In the future, we consider a processing to detect boundary edges correctly and a processing to prevent edges transforming to improve our method.

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