Detection of navigation route in greenhouse environment with machine vision

Haiqing Wang, Changying Ji, Qiu An, Qishuo Ding

Haiqing Wang, Changying Ji, Qiu An, Qishuo Ding, "Detection of navigation route in greenhouse environment with machine vision," Proc. SPIE 8349, Fourth International Conference on Machine Vision (ICMV 2011): Machine Vision, Image Processing, and Pattern Analysis, 83491P (13 January 2012); doi: 10.1117/12.920921

Event: Fourth International Conference on Machine Vision (ICMV 11), 2011, Singapore, Singapore

Detection of Navigation Route in Greenhouse Environment with Machine Vision

Haiqing Wang, Changying Ji*, Qiu An, Qishuo Ding
Key Laboratory of Intelligent Agricultural Equipment of Higher Education Institute in Jiangsu Province/College of Engineering, Nanjing Agricultural University, Nanjing, China
E-mail: chyji@njau.edu.cn

ABSTRACT

A route detecting algorithm was proposed for the cucumber picking robot navigation in greenhouse environment. Possible navigation route was determined from the additive value of the column scanning results. Color difference between cucumber plants and the mid row soil was analyzed through combining the RGB elements segregations with extra-green (ExG) value and extra-red (ExR) value. The obtained gray image was segmented with OTSU threshold method, which made the gray-color abruptly changed pixels along the two sides of the central line identified. Mean value of these selected pixels in each line was calculated to provide the discrete points along the navigation route. Finally least square method was used to fit these discrete points to provide the navigation lines, from which, the route for current navigation scheme can be determined. The proposed algorithm was applied to multiple images for its high speed and anti-noise verification.

Keywords: greenhouse; machine vision; cucumber; vision navigation; navigation route

1. INTRODUCTION

The green house environment was complicated by its inherent non-structural properties, such as the unpredictable shading, sunshine and terrain conditions. All these factors contribute to an enhanced difficulty in cucumber picking cucumber picking robot navigation inside greenhouses. The development of robot navigation has resulted in six main types of technologies, including map-based navigation, land sign-based navigation, machine vision-based navigation, GPS navigation and triangle laser-measurement navigation [1, 2]. The current studies on navigation of agricultural machinery are mainly concentrated on machine vision and GPS, which are considered the most promising navigation way [3, 4]. In the visual navigation, the visual adaptation is stronger and more flexible, which doesn't require pre-road map for navigation, so machine vision is very suitable for agricultural vehicle navigation between the lines [5]. In visual navigation of agriculture robot, the simplest way is to use artificial tag lines, which can be easily identified with the apparent characteristics of the tag line. This method is simple, convenient and low cost, but it requires simple working environment and good ground conditions. Another way is to identify the natural navigation route in complex agricultural scenes, images of the crop or fruit tree's mid-row spacing was usually used for searching the navigation route [6, 7]. Most of the currently used algorithm for this situation is the Hough transform, which has been proved effective in providing the navigation route lines [8, 9], but these traditional Hough transforming algorithms follow a thorough-searching strategy, resulting in a huge amount of calculation and requiring a large space of machine memory. Refinement on this type of computing technology can greatly reduce its complexity and improve its responding speed, but its convoluting capability still remains non-satisfactory [10]. Thus the least square method was tested to investigate the problem of navigation robot in greenhouse for a high efficient and real time route detecting strategy.

2. IMAGE ACQUISITION GREENHOUSE

Experiment was conducted in an ecological farm of Nan Linda, which is located in Nanjing, Jiangsu Province, China. On 15 August 2010, 30 images were taken in a sunlight greenhouse and stored in JPG format, the effective pixels of the

Fourth International Conference on Machine Vision (ICMV 2011): Machine Vision, Image Processing, and Pattern Analysis, edited by Zhu Zeng, Yuting Li, Proc. of SPIE Vol. 8349, 83491P · © 2012 SPIE
CCC code: 0277-786X/12/$18 · doi: 10.1117/12.920921

images are 640×480. The camera was situated at an above-ridge location amid two adjacent cucumber rows. The height of the camera from the ground was 1 m and the angle between the axis of the camera and the ground plane was about 30°.

3. THE CHARACTERISTICS OF GREENHOUSE IMAGE

On the one hand, the both sides' cucumber plants show obvious macro-segmentation boundaries, which are advantage to extract the navigation route; on the other hand, because of the tender of cucumber plants, leaves and stems, the images reveal that individual cucumber leave stretches to the interspacing of two rows, which leads to over-enlarge occupation of area in an image. This problem is aggravated in close shot and it significantly affects route detection.

The surrounding environment is complicated and constantly changing. This unavoidable interruption is resulted from the random distribution of cucumber stalk and leaves, the un-even ground and the variable soil moisture content, as well as the dynamical sunshine.

Pixel gray scale of cucumber plant is higher than that of the mid-row places, but it may be distorted by the varied distance and orientation of lighting. This problem is especially severe in long shot, and it can lead to an obscured state for cucumber stalk and road surface detection.

4. NAVIGATION ROUTE DETECTION

Image processing was operated in personal computer, which equipped with Pentium® Dual-core processor. The CPU frequency is 2.50HZ, the memory is 1G, and OS is Windows XP. All of algorithms proposed in this paper were computed in Matlab 7.0.

4.1 Possible navigation route determination

The RGB images were analyzed to deduce the possible locations of navigation routes on the scene. As the green element of the ground surface pixels has a lower value than that of the cucumber plant, the RGB image was scanned column by column from left to right. The sum of the green element value in each column was stored in an array ***Ci***, where i was the index of a column ($0 \le i < 480$). The histogram of green elements was plotted in Fig. 1 which illustrated the distribution of the total value of pixel's green elements of individual columns. The dashed line was the mean value of $\bar{C}$, which was calculated with the following equation:

$$\bar{C} = \frac{1}{640}\sum_{i=1}^{480} C_i \tag{1}$$

The leveled line $\bar{C}$ and the curve ***Ci*** intersected at two points, C_L and C_R(Fig. 1). The region in between the two points indicates a possible place where the navigation route could be located. A vertical line through the mid point of the two positions could be drawn, which specified an initial navigation line M. the equation for M as follows:

$$M = \frac{C_L + C_R}{2} \tag{2}$$

Where the C_L and C_R are the left edge and the right edge respectively, and M is the possible region for the navigation route in the image. Fig. 1 shows the possible route line M.

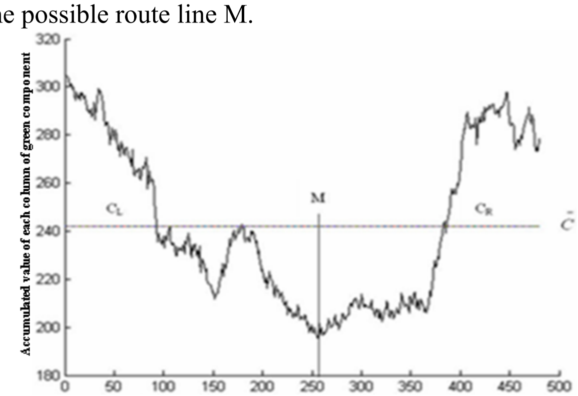

Figure 1. Vertical location of green value and the mean value of added green component of each column in the image (the vertical axis represents each column accumulated value of the green component; the horizontal axis indicates the number of columns in the image. The horizontal line identified the mean value of the curve).

4.2 Image preprocessing

The key to successful detection of route as species types is the segmentation of mid-row from background pixel regions effectively.

4.2.1 Colour transformation

The purpose on this task is to find a suitable algorithm capable of emphasizing areas considered as targets (the mid-row in an image) and transforming the RGB image to a gray scale image. By anlyzing the original image (Fig. 2, A), it can be seen that the green elements of inter-row places are largely different from that of the cucumber plants. To segregate the inter-row and the plants better, some methods were employed to enhance the green elements and fade the other colors. At first, two colour transformations were selected: The extra-green (ExG)[11], Eq. (3), because of its ability to emphasize the green colour, and the extra-red (ExR)[12], Eq. (4), because of its capacity of emphasizing the red colour.

$$ExG = 2G - R - B \tag{3}$$

$$ExR = 1.4R - G - B \tag{4}$$

Where the R, G and B stands for a pixel's red, green and blue color components respectively.

From the Equations.(3) and (4), the difference value (ExG-ExR)[13] was calculated for transforming the RGB image into gray image, which could further enhances the color difference between the inter-row ground and the plants. Fig. 2, B is the transformed image. After this process the image will be ready for segmentation.

4.2.2 Image segmentation

The local information of the cucumber plants aside the inter-row is un-predictable. Because of the dynamics of sunshine, shading and noise, which leads to an unstable state of the R, G and B elements proportion and the possible local fault segmentation. By comparing the potential algorithms suitable for this application, threshold segregating method should be considered first for segmenting the gray scale image. Taking into account the actual situation of the image gray scale

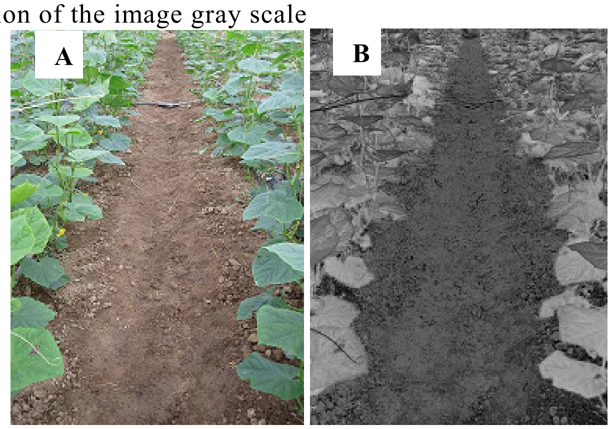

Figure 2. Original image and the gray image.
A, Original image. B, The result of transformation (the gray scale image).

distribution, the segregation required OTSU method [14], which is recognized as a good image segmentation algorithm, and it can be applied to segmenting different kind of images that have different characteristics and different quality. The pixel values were scaled to 0-255. In segmentation procession, the values of pixels (amid rows of cucumber plant) were set to 255 (white) if their values were lower than the threshold value, on the contrary, if pixel (cucumber plants) values were higher than the threshold, they were set to 0 (black). The segmentation procedure is relatively easier, but the binary image obtained from OTSU segmentation can not meet the requirements of the follow step of detection of navigation rout. Since there are many noises in background and groundsurface in image, it is nesassary to employed some methods for removing these noises in the image. The methods refer to the follows.

4.2.3 Binary image optimzation:

The clearance of the cucumber plants and leaves, the light and other factors can cause holes in the background of image, whose size is inconsistent and the position is uncertainty. The general mathematics Morphological methods, such as closing operation or expansion of filling, can reduce the holes or fill the holes in image and distort the outline of the object in image. These mathematics Morphological are not effective for large holes, therefore, it is nesassary to find a suitable method for filling holes. In addition, the isolated noises in the mid-row seriously affected the nivagation route detection, so some ways were used for removed the noises.

Two steps were used for processing this binary image with a high degree of accuracy.

a) Holes filling: Scan line filling algorithm was used to process the background, which is simple, low complexity, reliable and accurate. It could fill the 'white holes' of the background, but it could not deal with the isolated noise points.

b) Removing noises: After process described above, there were many isolated noise points. In binary image, the most difference was the pixel erea between the noises and the objects, which can be taken into account for removing

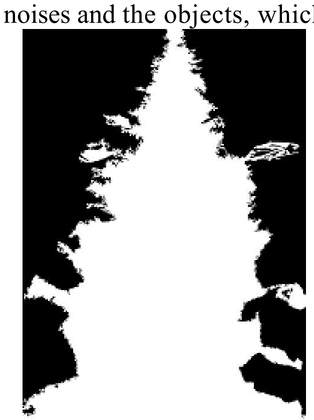

Figure 3. Binary image after preprocessing.

the noises by threshold erea method. In this step, isolated noises were erased from connected regions in binary image, the result of which was a satisfactory image with inter-row ground surface clearly separated from cucumber plants along the two sides. Fig. 3 shows the binary image after such preprocessing.

4.3 Detection of discrete points for navigation rout

Navigation route was formulated from the central position of the points. This was realized by searching the mutated points along the two sides of the M line, detecting the edge positions of the navigation route related to each line, i.e. the edges of navigation routes (Fig. 4, A). The edge point from the i^{th} line on the left side of a navigation route was coordinated as (p_{il}, q_{il}), that for the i^{th} line on the right side of a navigation route as (p_{ir}, q_{ir}). This allowed calculating the central point (p_{im}, q_{im}) amid the route with the following equation:

$$p_{im} = \frac{p_{il} + p_{ir}}{2} \text{ , } q_{im} = \frac{q_{il} + q_{ir}}{2} \tag{5}$$

where i=0, 1, 2…n

The navigation discrete points detected with this method were shown in fig. 4, B.

4.4 Formulation of navigation line

During the operating process, a robot would maneuver through a greenhouse while performing cucumber picking actions, it also possibly pause an instant to handle excessive picking works. Therefore it is necessary to detect its current track angle. The false route regions along the two sides of inter-row places may turn out banded navigation base lines, but the edges of the two sides are usually irregular. This allows a straight line to be drawn along the discrete points between two edges. Five such continuous points were used to calculate their mean value for further reducing the influence by minor texture and the local curvature near the edges. Then the least square method was applied to fit the navigation line, which is the simplest and most commonly

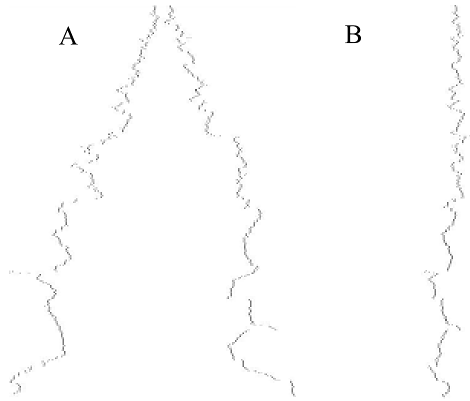

Figure 4. Discrete points in image.
A, the edge points of navigation route. B, the discrete points.

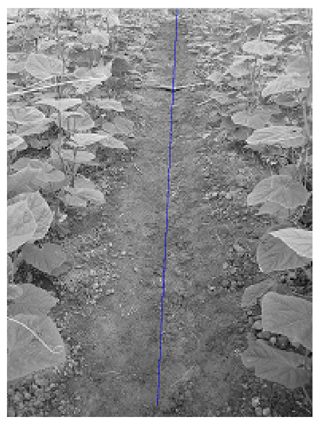

Figure 5. Result of the route detection on the gray image.

applied form of linear regression and provides a solution to the problem of finding the best fitting straight line through a set of points [15]. The average five-point coordinates were fitted a straight line as shown in Figure. 5.

5. RESULTS AND DISCUSSIONS

Fig 5 explained a route detecting image. It was found that, to some extent, the discrete points were affected by the inter-row weed and micro fabrics around edges. Some of them deviated significantly. But the 5 points averaging treatment ameliorated this effect, provided a statistical improvement on the result and largely stabilized the navigation route. In addition, data compassion was made to the discrete points, which resulted in a minor storage requirement and a quicker responding speed.

6. CONCLUSION

The greenhouse environment was carefully considered in this work and the least square method was adopted to fit the discrete points for robot navigation route detection. The technical solution was proved to be simple and stable, and was effective in avoiding the noise disruption. Navigation route can be quickly determined with a reduced computing load while providing detailed information to the cucumber picking robot. This route detecting algorithm can not only be used for cucumber picking but also for other vegetable productions in greenhouses.

ACKNOWLEDGMENT

This work was supported by the National High Technology Research and Development Program of China (No. 2006AA10Z259).

REFERENCES

[1] D Khadraoui, C Debain, R Rouveure, et al, “Vision-based control in driving assistance of agriculture vehicles,” The International Journal of Robotics Research, vol. 17, no. 10, pp. 1040–1054, 1998.

[2] Tillett N D, Hague T, Marchant J A, “A robotic system for plant-scale husbandry,” J. Agric. Eng. Res., vol. 69, no. 2, pp. 169–178, 1998.

[3] Hague T, Marchant J A, Tillett N D, “Ground based sensing systems for autonomous agricultural vehicles ,” Computers and Electronics in Agriculture, vol. 25, pp. 11–28, 2000.

[4] Wilson J N, “Guidance of agricultural vehicles-a historicalperspective ,” Computers and Electronics in Agriculture, vol. 25, pp. 3–9, 2000.

[5] Zhou Jun, “Research on visual navigation for agriculture wheeled mobile robot,” Nanjing: Nanjing Agricultural Universty, 2003.

[6] Feng Jiannong, Liu Ming, Wu Jie, “Survey of intelligent navigation of autonomous mobile robot,” Robot, vol. 19, no. 6, pp. 468–472, 1997.

[7] Keicher R, Seufert H, “Automatic guidance for agricultural vehicles in Europe,” Computers and Electronics in Agricuture, vol. 25, no. 1–2, pp. 169–194, 2000.

[8] Rovira-Ma’s F, Zhang Q, Reid J F, et a.l, “Hough-transform-based vision algorithm for crop row detection of an automated agricultural vehicle,” Proceedings of the IMechE, PartD: JournalofAutomobile Engineering, vol. 219, no. 8, pp. 999–1010, 2005.

[9] Zhao Ruijiao, Li Minzan, Zhang Man, Liu Gang, “Rapid crop-row detection based on improved Hough transformation,” Transactions of the Chinese Society for Agricultural Machinery, vol. 40, no. 7, pp. 163–165, 2009.

[10] LeiXu, ErkkiOja, Pekka Kultanen, “A new curve detection method: randomized Hough transform (RHT),” Pattern Recognition Letters, vol. 11, no. 5, pp. 331–338, 1990.

[11] Woebbecke, D.M. et al., “Shape features for identifying young weeds using image analysis,” Trans. Am. Soc. Agric. Eng, vol. 38, no. 1, pp. 271–281, 1995.

[12] Meyer, G.E., Hindman, T.W., Lakshmi, K., “Machine vision detection parameters for plant species idetification,” SPIE, Bellingham, WA, 1998.

[13] Neto, J.C., “A combined statistical-soft computing approach for classification and mapping weed species in minimum tillage systems,” University of Nebraska, Lincoln, NE, 2004.

[14] Ostu N. Discriminant and least square threshold selection[C] // In: Proc 4IJCPR, 592–596, 1978.

[15] Weisstein, Eric W, "Least Squares Fitting." From MathWorld--A Wolfram Web Resource. http://mathworld. wolfram. com/ Least SquaresFitting. html