Development of Picking Robot in Greenhouse Horticulture

S. Kitamura [1], K. Oka, F. Takeda

1 Kochi University of Technology, 185 Miyanokuchi, Tosayamada-cho, Kochi, 782-8502 Japan
Phone:+81-0887-57-2245, Fax:+81-0887-57-2320
E-mail:075031e@gs.kochi-tech.ac.jp

Abstract: This paper describes development and experiments of a picking robot for sweet peppers in greenhouse horticulture. This picking robot has an image processing system with a parallel stereovision, a camera positioning system to follow the sweet pepper by visual feedback control, and a cutting device. A prototype robot system has been made and is introduced. Experiments of the prototype prove that performance of the cutting system depends on recognition of fruits of sweet peppers. Consequently, the robot has ability for picking sweet peppers.

Keywords: Picking Robot, Image Processing, Recognition, Visual Feedback Control, Stereovision, Sweet Pepper, Greenhouse.

1. Introduction

In Japan, greenhouse horticulture is flourishing as shown in Fig.1. Greenhouses are covered with vinyl sheets, and keep vegetable from farming enemies such as strong wind, bad weather, harmful insect, and so on. Greenhouse horticulture help agricultural products to grow more efficiently and keeps them high quality because of the controlled circumstance. In recent years, the shortage of farming labor force is getting worse because of impact of the falling birthrate and the aging farmers. For the solution of this problem, some automatic greenhouse horticulture systems have been proposed. They are, for example, automatic temperature control system, automatic watering system, automatic picking system, and so on. Automatic temperature system and automatic watering system have been investigated. Picking robots for eggplant and tomato have been also studied [1][2]. However, their picking robots have not been put to practical use in greenhouse horticulture.

The difficulty of picking robots exists in identification of fruits, cutting systems, moving systems, and so on. Recognition of fruits is newly carried out by image processing using camera. Therefore, the picking robot system for the fruit that has special color such as eggplant and tomato has been investigated. Although sweet pepper is major agricultural produce in greenhouse horticulture, its picking robot has not been studied. Because the color of fruits is almost same of leaves, and recognition of the fruit is difficult.

This paper aims development and a feasibility study for the picking robot of sweet peppers using usual image processing technique we constructed the recognition system of sweet peppers and its position, camera positioning system for cutting the stem, and picking robot using these systems. In the results of experiments, if the fruit of the sweet pepper was sharply defined, this robot could cut the stem of the recognized sweet pepper. First, the picking operation for sweet peppers in greenhouse by farmers is introduced. Second, the outline of the picking robot for sweet peppers is explained and prototype of the robot is introduced in detail. Third, the recognition system of sweet peppers control system is explained. Last, the result of experiment is introduced.

2. Picking robot

2-1 Picking operation by farmers

Sweet pepper trees are planted on chins in greenhouse as shown in Fig.2 (a) and sweet peppers are growing on trees as shown in Fig.2 (b). Sweet peppers that are within the standard are picked by farmers. The procedure to pick sweet peppers is follows. First farmers look for sweet peppers that meet the standard of its size/shape with their eyes and hands. They cut stems of the selected sweet peppers, and put into the container as shown in Fig.2(c).

Fig.1 photograph of greenhouse

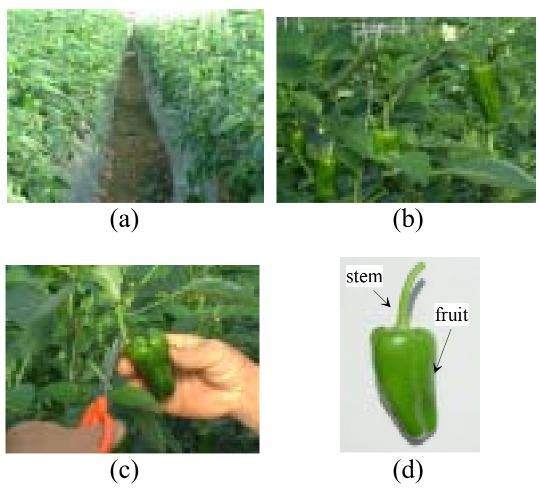


Fig.2 Greenhouse horticulture for sweet peppers

2-2 Over view

Our study is the development of picking robot that can recognize sweet peppers, cut it, and put it into the container as farmers. Functions are required for this picking robot as shown in Fig.3. They mainly consist of recognition technology, the picking technology, moving technology. For these functions, this picking robot has an image processing system with a parallel stereovision, a positioning system to follow sweet pepper by visual feedback control, and a cutting device. A prototype robot is shown in Fig.4. This robot is about 1000mm wide, 550mm deep, 1400mm high. When the wheels do not move, operating ranges are 230mm in the horizontal, 180mm in the vertical, and 180mm in the depth. In this range, it is possible to cut the stems of recognized sweet peppers. The cutting device that is fixed to the frame where two cameras are installed can move 80mm forward, and it can cut the stem of the recognized sweet pepper by a pruner.

2-3 Camera positioning and image processing systems

For getting size of a fruit of a sweet pepper and positioning to cut the stem of the recognized sweet pepper, positioning system by cameras for the recognized sweet pepper is used. For positioning, we use visual feedback control. Two cameras can be positioned on the three directions (horizontal, vertical, depth) using DC motors, timing pulleys, timing belts, and slide rails. The outline of the camera positioning system is shown in Fig.5. This positioning system is used visual feedback control system as shown in Fig.6. The position of sweet pepper is sensed by two cameras. By these position data, each motor is controlled using DSP controller.

The image processing system consists of two color CCD cameras, a capture board, and an image processing application as shown in Fig.7. This camera is a high image –quality CCD camera of RF SYSTEM whose specification are 680,000-pixel 1/4inches CCD and 450 TV lines resolution. The image capture board is PicPort of Leutron, and the image processing application is HALCON of MVTec. Two cameras are placed in parallel, because we detect the position of the sweet pepper by stereovision. Two cameras capture the color image, and the images are processed by our created algorism.

2-4 A cutting device

A photo of the cutting device is shown in Fig.8, we used parallel linkage mechanism with a pruner as shown in fig.9. This pruner can be opened/closed about 0 to 30 degrees by the DC motor control. This pruner is sold at any market, and its grip is got out for getting on the parallel linkage. When the pruner is got on the parallel linkage, we used the springs and set collars. Consequently, this pruner is easily demountable, because it has a possibility to keep cut sharply by grinding. This manipulator is driven by rack/pinion

.

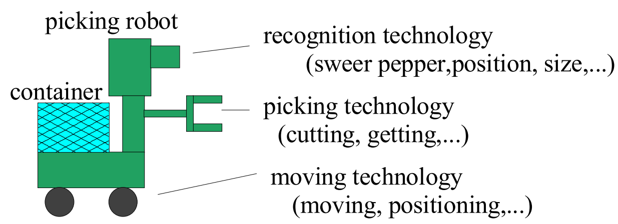


Fig.3 The concept for picking robot

Fig.4 Over view picking robot

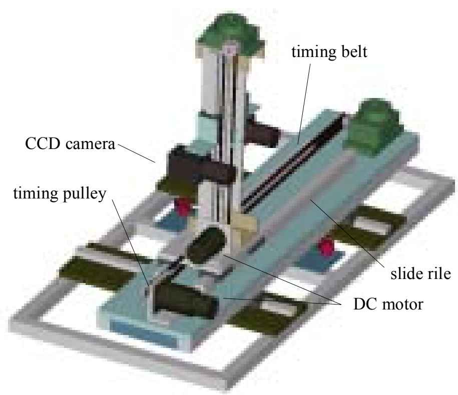


Fig.5 Camera positioning system

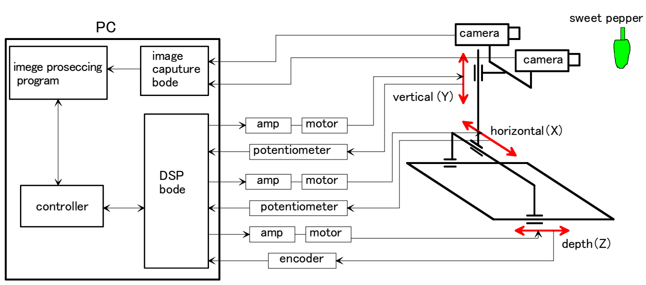


Fig.6 Visual feedback control system

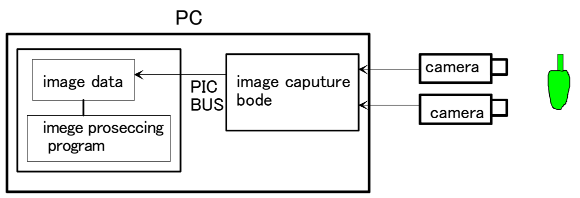


Fig.7 Image processing system

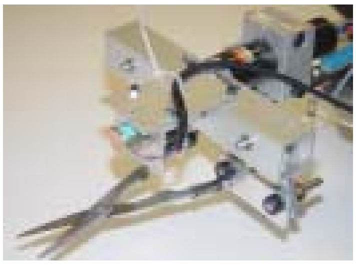


Fig.8 Cutting device

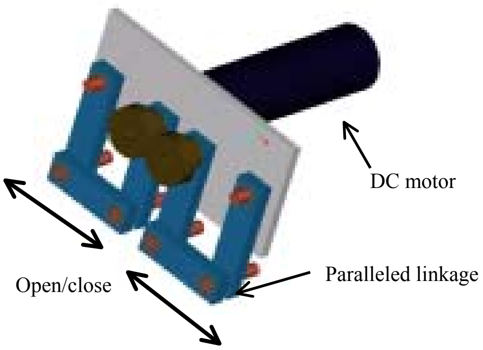


Fig.9 Paralleled linkage mechanism

3. Image processing

3-1 Recognition

In this image-processing algorithm, the fruit of the sweet pepper is recognized by binarization of HSI color specification system, labeling, and selection feature [3]. HSI color specification system is one of numerical expressions, it consist of three images that are hue, saturation, intensity. The flow of this algorism is shown in Fig.10. For differentiating fruit and leave, this system need lighting to sweet peppers. The color of fruit is the almost same color of leave, so only this algorism cannot recognize the fruit in the image of with leaves. But when sweet peppers are lighted, the gray values of fruit are different from it of leaves in the saturation of HSI, so only fruit is recognized by this algorism in the image with leaves. The change of gray value by lighting is shown as Fig.11, and the example of image processing is shown as Fig.12.

3-2 stereovision

By stereovision of the two cameras, the distance between the camera and the recognized sweet pepper can be measured as shown in Fig.13. The points of x-coordinate of two sweet peppers in each captured image are difference. The distance d is calculated with the difference $(xl - xr)$ from (1) [4]. This image processing system can recognize the fruit of the sweet pepper, and it can get the 3-D information of the fruit.

$$d = bf \big/ (x\ell - xr) \tag{1}$$

Where f : focal length, d : distance of two cameras. This time, we defined $k = bf$ that was found by actual measurement, and we used (2) for calculating of its distance.

$$d = k \big/ (x\ell - xr) \tag{2}$$

4. Visual feedback control

This visual feedback control block diagram is shown in Fig.14. This positioning system is operated as follows. First, two CCD cameras capture the color images, as a fruit of a sweet pepper is recognized on each images. From the center positions of the recognized fruit images, the depth position of it can be calculated. In this positioning system, the center of fruit is aligned with the reference center by moving the camera as shown in Fig.15.

5. Experiment and result

Experiments were carried out in our laboratory and a greenhouse. In our laboratory, the developed picking robot could recognize the fruit of the sweet pepper and cut the stem of it as shown in Fig.16. In a greenhouse as shown Fig.17, if a fruit of sweet pepper was sharply defined, the developed picking robot could recognize the fruit of the sweet pepper and cut the stem of it. The fruit was not sharply defined, for example, the leaves hide the fruit of the sweet pepper, this robot could recognize a part of the fruit by cameras, but it could not the stem of the recognized fruit.

6. Conclusion

In this report, a picking robot for sweet peppers in greenhouse horticulture has been introduced, and experimental results have been shown. In the results, if the fruit of sweet pepper sharply defined this picking robot can recognize fruits of sweet peppers and cut the stems of them. . However, when the fruit is not sharply defined, this robot cannot cut. The improvement of ability to recognition rate and the cutting point will be studied in the future research.

References

[1] S.Arima, S.Yuki, J.Yamashita, T.Katou, K.Marumi, Studies on Harvesting Robot for Strawberry Grown on Annual Hill Top, ROBMEC'03, 1P1-2F-A5, 2003.

[2] M.Morita, K.Namba, T.Nishi, "Teleperrating Robotics in Agriculture", ROBMEC'03, 1P1-2F-A1, 2003.

[3] K.Oka, S.Kitamura, Picking Robot in Green House –A Study of Image Recognition for Sweet pepper–, 2003.

[4] N.Suganura, N.Fujiwara, K.Senda, "Lane Marker Extraction on the Highway Using Stereovision System and Active Contour Model," ROBMEC'03, 2A1-1F-C3, 2003.

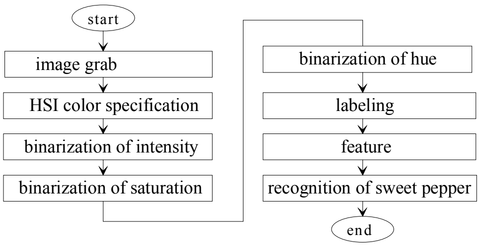
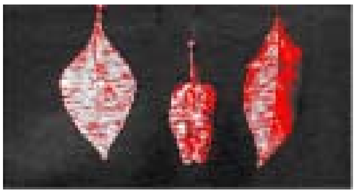
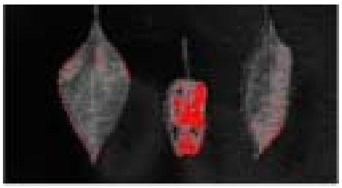


Fig.10 Image processing algorism for recognition of sweet pepper



(a) Grey value without light



(b) Grey value with light

Fig.11 Change of gray value by light

Fig.12 Recognition of sweet pepper

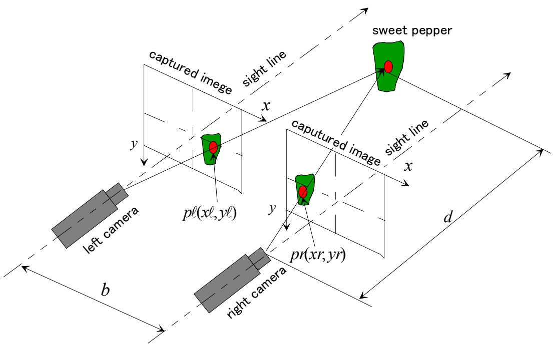


Fig.13 Parallel stereovision

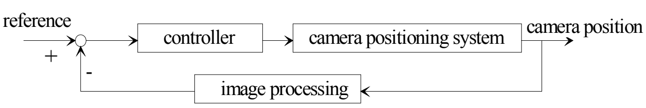


Fig.14 Visual feedback control

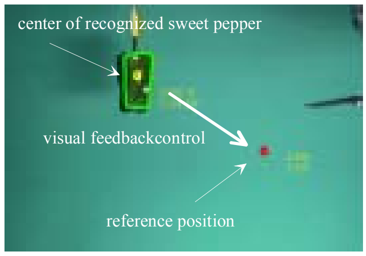
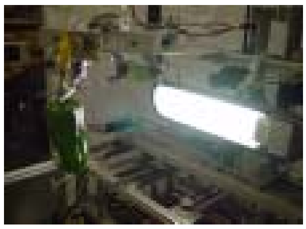


Fig.15 Visual feedback control in image

(a)

(b)



(c)

(d)

Fig.16 Result of experiment without leaves

Fig.17 Photograph of picking robot in greenhouse horticulture