Sweet Pepper Picking Robot in Greenhouse Horticulture

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Abstract. *This paper describes recognition and cutting system of sweet peppers for picking robots in greenhouse horticulture. This picking robot has an image processing system with a positioning system for two cameras and cutting a device to follow the sweet pepper by visual feedback control. A prototype robot system is introduced. Experiments of the prototype robot prove the 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, Visual Feedback Control, Sweet Pepper

1 Introduction

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 operation by farmer

Sweet pepper trees are planted on chins in greenhouse and sweet peppers are growing on trees as shown in Fig. 1. 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

Fig. 1: Photograph of sweet pepper growing

Fig. 2: Picking of sweet peppers by farmer

3 Picking robot

Our study is the development of picking robot that can recognize sweet peppers, cut the stem, and put the fruit into the container as farmers. Main functions required for this picking robot are shown in Fig. 3. They are a recognition technology, a picking technology, and a moving technology. To realize for these functions, the picking robot has an image processing system with a parallel stereovision, a positioning system to follow the recognized sweet pepper by visual feedback control, and a cutting device.

An illustration and a photo of a picking robot is shown in Fig. 4. This robot is approximately 1000mm wide, 550mm deep, and 1400mm high. When wheels do not move, operating range is 230mm in the horizontal direction, 180mm in the vertical direction, and 180mm in the depth direction. Within the range, it is possible to cut the stems of the recognized sweet peppers. The cutting device is fixed to the frame where two cameras are installed. It moves 80mm in the forward direction, and cuts the stem of the recognized sweet pepper by a pruner.

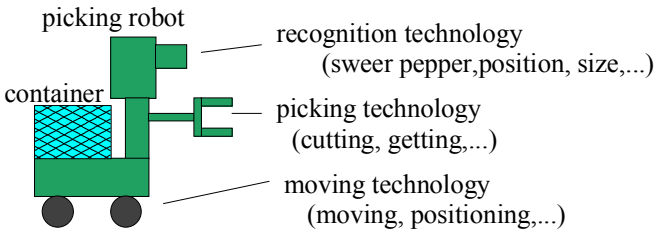


Fig. 3: Conceptual illustration of picking robot

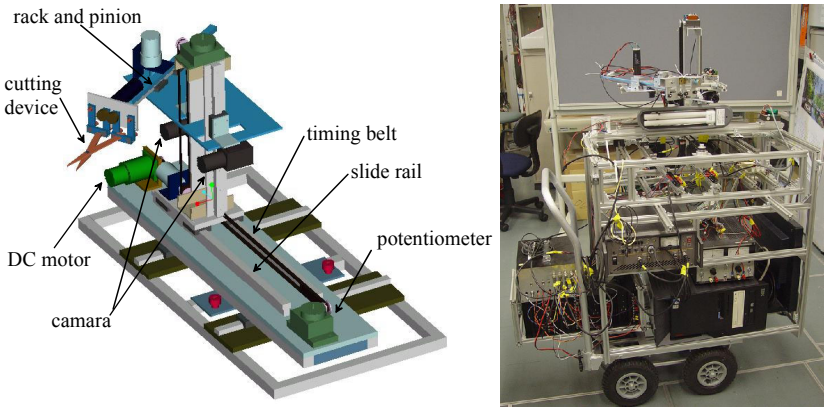


Fig. 4: Structure of picking robot

The image processing system consists of two color CCD cameras, a capture board, and image processing applications. The 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, detect the position of the sweet pepper can be detected by stereovision method.

To cut the stem of the recognized sweet pepper, positioning system uses the feedback loop with cameras for the recognized sweet peppers. In this positioning system, camera can be positioning as it follows the sweet pepper in the three dimensions, horizontal direction, vertical direction, and depth direction. The positioning system has slide rale, timing belt, and DC motor in each dimension. All motors controlled by DSP controller. Image processing system provides the information of the position of the sweet pepper to the controller. Based on the information the positioning system controls the camera position. The positioning system of the camera is shown in Fig. 5.

In the image-processing algorithm, the fruit of the sweet pepper is recognized by binarization of HIS colour specification. HSI colour specification system is one of colour image expressions, it consist of three images that are hue, saturation, and intensity. However, this algorism cannot recognize fruits without enough lighting.

Fig. 6 shows examples of the results of recognition in images with leaves. An image without light is (a) and the result of recognition is (c), and an image with light is (b) and the result is (d). As the colour of fruits is almost same colour of leaves the system needs lighting for peppers to identify a fruit from leaves. A series of the processing images of the proposed method are shown as Fig. 7.

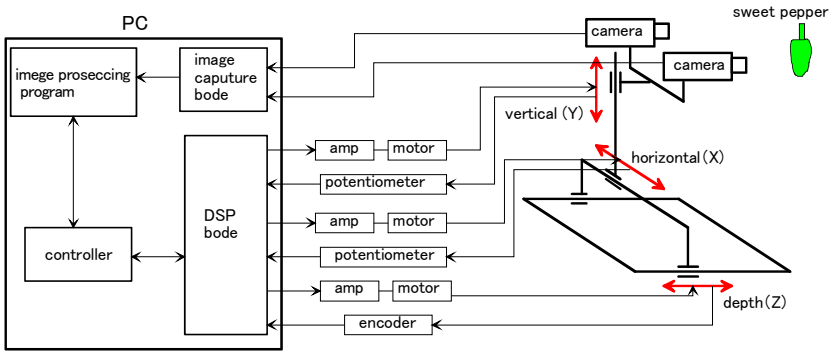
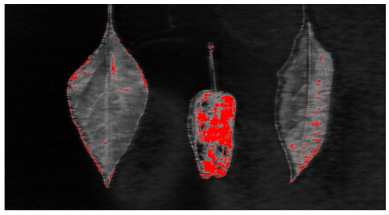


Fig. 5: Camera positioning system with visual feedback

(a) Image grab without light

(b) Image grab with light

(c) Grey value without light

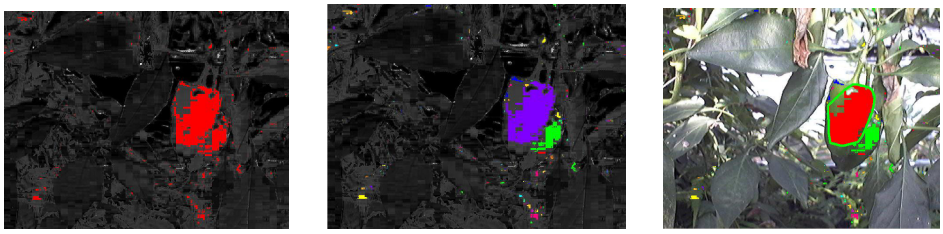


(d) Grey value with light

Fig. 6: Difference of recognized results by light

The positioning system of cameras controls three actuators for the frame which has a cutting device and cameras by visual feedback control as shown in Fig. 4 and Fig. 5. The system is operated as follows. First, two CCD cameras move around with capturing the color images as a fruit of a sweet pepper is recognized on both images. After the fruit has been caught, the center of the fruit is made to align to the reference center as shown in Fig. 8. Last, the depth position is calculated from the center positions of the both recognized fruit images, and actuates the frame in the depth direction until reference depth position.

(a) Image grabs (b) Binarization(intensity) (c) Binarization(saturation)



(d) Binarization (Hue) (e) Labelling (f) Feature quantity

Fig. 7: Example of image processing

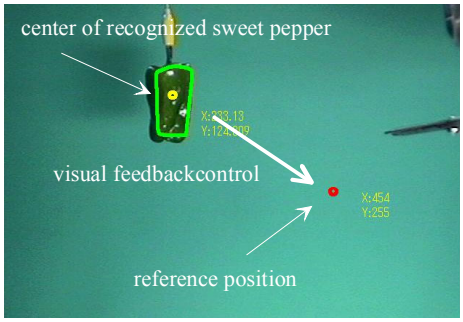


Fig. 8: Visual feedback control in image

4. Experiment and result

Experiments were carried out in two cases. One is without leaves as shown in Fig. 9 and anther is with leaves as shown in Fig. 10. In the experiment without leaves, the sweet pepper was set in front of the picking robot as shown in Fig. 9. First, two cameras moved in the horizontal and vertical, to look for the sweet pepper by the image processing. When the left camera recognized the sweet pepper, the left camera was controlled to positioning to the recognized sweet pepper using the visual feedback as come to the center position of the image. After the positioning in the two directions converged, the camera positioned to the sweet pepper in the depth direction with the stereovision method. When the positioning in the depth direction finished, the link is slid and the cutting device is approaching to the stem, and cut it. After the cutting of stem, this robot returns to the initial position. In this case, the recognition of the fruit and the cutting of the stem went well. Another sweet peppers operation also went well.

In experiment with leaves, all of sweet peppers shown in Fig. 10 could be recognized, and the fruits of the left side and the center could be cut. But the fruit of the right side was failed in cutting, because leaves covered the stem where the pruner would cut.

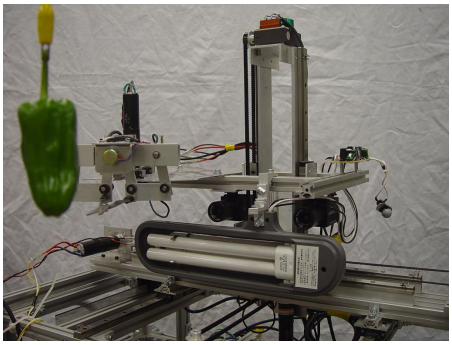


Fig. 9: Experiment of picking robot without leaves

Fig. 10: Experiment of picking robot with leaves

5. Conclusion

A picking robot for sweet peppers in greenhouse horticulture has been developed. In this paper, the developed prototype robot has been explained about functions and each part, and the results of the experiments have been shown. The functions roughly divided into the recognize system for the fruit of sweet peppers and cutting system. The robot has recognition system and cutting system. In the recognition system, we used image processing with lighting and stereovision. In the cutting system, we developed the camera positioning system with visual feedback control and cutting device. In addition, we carried out experiments in two simple situations in the laboratory. First experiment was carried out without leaves, and recognition of the fruit and cutting the stem was succeeded. Second experiment was carried out with leaves. In the case, recognition was succeeded, but success rate of cutting the stem became low because leave covered the stem.

References

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