THE STUDY ON HARVESTING ROBOT BY TARGET POINTING METHOD BASED ON IMAGE PROCESSING

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ABSTRACT

Nowadays agricultural robots are the most important technology in Japan. Compare to the industrial robots, agricultural robots are hardly to use because a target is living thing. From this reason, agricultural robot focused on fruit harvesting had been studied. In this paper, the robot system, which makes a robot identifying a target by pointing the position in order to harvest flexibly and quickly, is explained. According to this system, the robot is able to identify the target at difficult discovery position. And this harvesting speed is as same as human operation. Therefore this harvesting system is considered that it has more efficient operation than human.

Keyword: Selection Work, Image Processing, Focus Length, and Distance Sensor

1. INTRODUCTION

Recently Japanese agriculture is serious situation. The typical example is food self-sufficiency ratio. In present, our food self-sufficiency ratio is 40% and grain self-supporting ratio decrease to 27%. Therefore the ministry of agriculture, forestry and fisheries of Japan has plans to increase our food self-sufficiency ratio to 45% within 2010. However, it is difficult to succeed because of negative factors of agricultural such as agricultural population decline and aging of the agricultural population. To solve these problem, it needs further mechanization and automation in order to improve the quantity and quality of production and also laborsaving. In this background, Japanese agricultural machinery has progressed centering on a rice machine. Refer to agricultural machinery, rice working time per 1,000m^2 sharply decrease from 141 hours in 1965 to 38 hours in 1996. In the other hand, the mechanization for fruit is not in progressing. Compare to rice harvesting, fruit can not be harvested spontaneously because of their different size and height. Moreover it is necessary to harvest only suitable fruit. Therefore it is important to develop mechanization for harvesting in selected position. One choice of this is agricultural robot.

2. SELECTION WORK

The agricultural robot is expected to do automatic selection work which has complex mechanism. The reasons are described the following:

1. Although the targets are the same type but they are different in shape, color, physical properties, etc.

2. It is difficult to identify the position of target because of noises such as leaves, branches, the ground, and the sky.

3. Optimum harvesting time should be considered in order to add the value to the target.

In these work, it is good that human and robot work together to combine the good point of them. Human has high ability to identify and judge what the suitable target is. For the robot it is not necessary to take a rest. At first, human will identify the position of the suitable target quickly, after that the robot will harvest the target quickly too. And considering the collaborative work, the way of pointing as interface between human and robot should be easy so that it can be done by anyone. From the following chapter, the system structure and the target pointing method are described.

3. SYSTEM STRUCTURE

Experimental equipment is shown in picture 1 and 2.

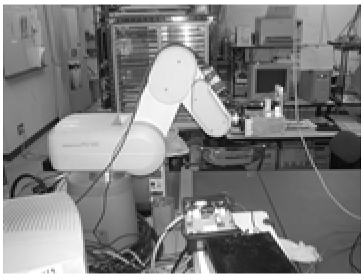


Fig. 1: Harvesting Robot

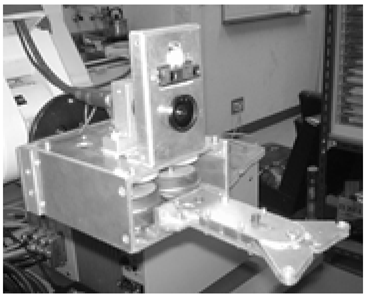


Fig. 2: CCD camera and PSD on the wire hand

There are Charge Couple Device camera (CCD camera) and Position Sensitive Device (PSD) on wire hands of the robot. The HALCON software by LINX Cooperation processed the image from CCD is used. This software can control the robot with RS-232C serial port. GINGA REAL by LINX Cooperation is used as image processing board. In order to convert from PSD [GP2D12 by SHARP] analog signal to digital signal, PIC 16f873 microchip is used. And laser pointer is used in order to guide to location of the target.

The system flow can be divided into 3 steps. First, the worker points the position of the target with laser pointer, after that it is identified by the robot via image processing. Next, the angle between the target and the robot will be calculated. The robot turns around to the front of the target and moves towards the target by using PSD (distance sensor). The last step, the robot harvests the target.

4. LASER SPOT IDENTIFICATION

Three principles to identify the laser spot by CCD camera are explained here. The first principle is movement of laser pointer used by the worker. It is difficult for the worker to point at the same place for long time. Therefore, laser spot can be define as moving object which is extracted by using image processing from full image. Each image processing takes series of three successive images which are $f_{i-1}(m,n)$, $f_i(m,n)$ and

$f_{i+1}(m,n)$ in order to extract only the moving object, where $f_{i-1}(m,n)=$ image of coordination of m and n at time i-1, $f_i(m,n)=$ image of coordination of m and n at time I, and $f_{i+1}(m,n)=$ image of coordination of m and n at time i+1. The subtaraction image $[s_i(m,n)]$ needs to extract the spot and it is gained from this equation.

$$s_i(m,n)=\left|f_{i-1}(m,n)-f_i(m,n)\right|$$

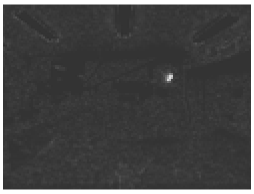
However, only this process is not enough because noises such as unnecessary background data, double extraction object, and other noise may be included in this subtaraction image. So the logical multiplication $[L_i(m,n)]$ which is obtained from the following equation needs to omit those noises.

$$L_i(m,n)=s_i(m,n)\bullet s_{i+1}(m,n)$$


$f_{i-1}(m,n)$ $f_i(m,n)$

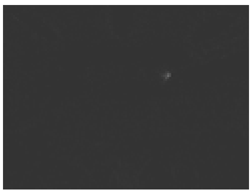
$f_{i+1}(m,n)$

Fig. 3: Three successive image




$s_i(m,n)$ $s_{i+1}(m,n)$

Fig. 4: Subtraction image



$L_i(m,n)$

Fig. 5: Logical multiplication image

The second principle is color. It is observed and separated for color difference. In this work, the wavelength of laser is in the range of 650nm-670nm. The filter which can transmit the light in this wavelength is used to transmit only laser spot to CCD camera.

Before filtering *After filtering*

Fig. 6: Color separation image

The last principle is intensity. Laser intensity is used to distinguish laser beam from other object. Because laser beam is brighter than other light thus the brightest spot can defined as laser spot.

Fig. 7 Final image

5. CALCULATION OF THE ANGLE TO THE TARGET.

After identification of the laser spot in the camera image, the robot controlled by the system turns to the front of the target, and then a laser spot comes to the center of camera image. From the result of image procerssing, the angle between the target and the camera is calculated by using the focus length from this equation.

$$\theta = \tan^{-1}\frac{H}{F} \quad \cdots(A)$$

where H is the difference of pixel between center of camera and the spot position, F is the focus length. Generally, [pixel] is used as the unit of the heigth and [mm] is used as the unit of focus length; therefore it is necessary to convert the unit of focus length into [pixel] by calibration expeiment.

The methods to calculate the focus length are described below.

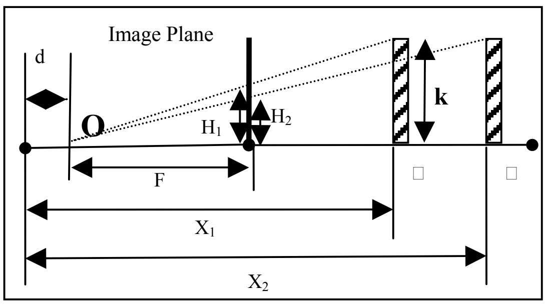


Fig. 8: Calibulation experiment

At first, the real target height at piont A, k is measured. Then, the height H_1 is measured at image plane by image processing. The distance of target from the origin is x_1. In the same way, the height H_2 at point B whose distance from the origin is x_2 is measured at image plane. H1 and H2 can be calculated from the following equations.

$$\frac{H_1}{F} = \frac{k}{x_1 - d} \qquad \cdots(1)$$

$$\frac{H_2}{F} = \frac{k}{x_2 - d} \qquad \cdots(2)$$

where [d] is the measuring error. Constant K in equation 1 and 2 are the same value thus d can be expressed as equation (3)

$$d = \frac{H_2 x_2 - H_1 x_1}{H_1 - H_2} \qquad \cdots(3)$$

Combining equation (1) to (3) and rearrangeing, focus length can be expressed as

$$F = \frac{H_1 H_2 (x_2 - x_1)}{k(H_1 - H_2)} \quad [pixel]$$

The angle to the target can be calculated from formula (A).

6. MEASURING OF THE DISTANCE TO THE TARGET

After turning to the front of target, the robot with PSD on the wire hand can approach to the target. PSD is the sensor that can calculate the distance from the infrared light. Although this device gives the data in the voltage form, but the relation between the distance and the voltage is not constant. It is important to adjust this relation by calibration experiment. To measure color error, changing the color of experimantal target such as red, blue, yellow, black and white is established.

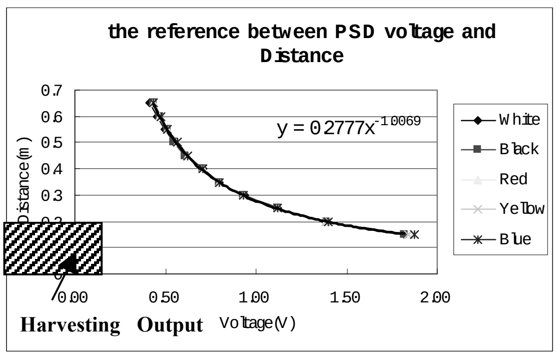


Fig.8: The relation between PSD voltage and distance from PSD

This graph shows the experimental result which is precise relation. Color difference has no effect to output. Approximate formula of PSD output is shown below.

$$D = 0.2777V^{-1.0069}$$

Where D is distance from PSD to the target, [mm] and V is PSD output voltage [V]. From this experiment, the distance from PSD to the target can be calculated by using approximate formula.

7. EXPERIMENT AND RESULT

The experiment using the system mentioned above was set in the laboratory which does not have wind. It is not real environment. Accuracy of robot movement, distance which can identify spot position, and harvesting hours are detected and the result is is shown as the figure.

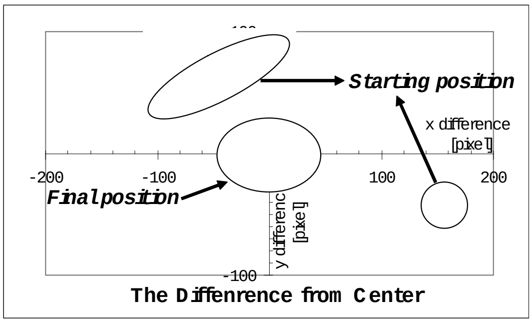


Fig. 9: The pixel deference between camera center and spot position

This graph showed the difference of pixel between camera center and spot position. According to this graph, the robot can move directly toward target, which can be exists anywhere.

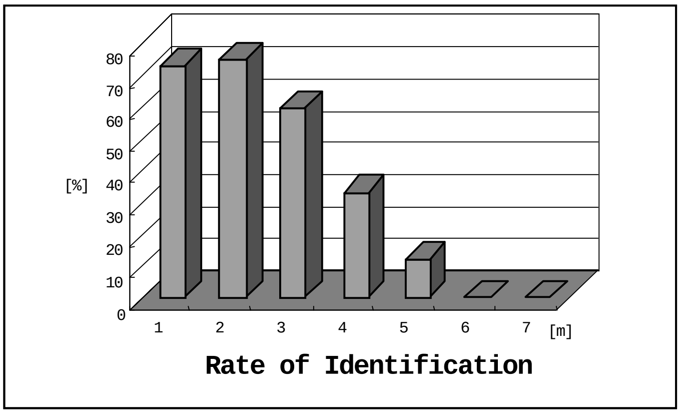


Fig. 10: The accuracy of image processing

This graph showed the accuracy of image processing, which identify the target at each distance. According to the graph, the farthest spot can be identified is 5 meters; however this distance has low identification rate. Therefore the harvestable distance is about 3m.

Compare to human operation, harvesting hours of the robot is longer than that of human. The robot took 11 seconds per target (5 seconds for human work, and 6 seconds for robot work) while human took 10 seconds. But compare to only human work hours, this system takes only half seconds.

8. DISCUSSION

From the experiment, it was found that the agricultural robot was able to harvest flexibly with the target pointing. Although robot harvesting speed is slower than human operation speed, human can not work in the same speed for a long time. Therefore we can conclude that harvesting speed of robot is almost as same as that of human. Moreover the human work hours can be reduced to half. It is efficient enough to replace human operation by this robot system.

In case of the target locates very far from the robot and it cannot detect the laser spot , the target can not be harvasted. Methodology of pointing and transportation devices will be improved in order to solve this problem.

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