DEVELOPMENT OF 3-D POSITION DETECTING TECHNIQUE BY PAN/TILT

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ABSTRACT

It is very difficult to mechanize tomato harvesting because identifying a tomato partly covered with leaves and stalks is not easy. This research was conducted to develop tomato harvesting robot which can identify a target tomato, determine its three dimensional position, and harvest it in a limited time. Followings were major findings in this study

The first visual system of the harvesting robot was composed of two CCD cameras, however, this could not detect tomatoes which are not seen on the view finder of the camera especially those partly covered by leaves or stalks. The second visual device, combined with two CCD cameras and pan/tilt procedures was designed to minimize the positioning errors within ±10mm, but this is still not enough to detect tomatoes partly covered with leaves etc. Finally, laser distance detector was added to the visual system that could reduce the position detecting errors within 10mm in X-Y direction and 5mm in Z direction for the partly covered tomatoes.

Key Word: Tomato, Image processing, Harvesting robot

INTRODUCTION

Recently, the proportion of greenhouse tomato growing area of the total tomato cultivation area has significantly increased in Korea, 50% in 1970, 94%(4,106ha) in 1998, which means much more works should be done in hot and humid working conditions.

Recently, many agricultural robots are being developed for use in harvesting, grafting and transplanting robot. etc. applying advanced industrial robot technologies.

For a tomato harvesting robot, there is a need to develop a vision system to recognize and detect three-dimensional position of the target object, manipulator, and end-effector to pick it up. With the stereo image processing technology two cameras are used for recognizing and 3-D positioning. It is important to calibrate the differences of each color components, the amount of exposure and focus of each camera by software.

If the target object is not on the center of the lens of any of the two fixed cameras, the positioning error will increase due to the distortion phenomenon of the lens, If the fruit is too close to any lens of the two, the distance could not be measured as the stereo image could not be obtained without the other image.

Moreover, the differences of size and shape of fruits, the overlapping of a couple of fruits, and partly covered fruit with leaves and stalks affect the 3-D positioning accuracy.

For a mini-tomato harvesting robot, Kondo et al(1996) developed a vision system using the phase difference of projected two images on 2-D plane, articulated manipulator, vehicle device and an end-effector that cut off the tomato after vacuum suction

Subrata et al(1996) also developed a visual device for mini-tomato harvesting robot which can distinguish the ripened fruits from the unripened fruits and leaves by using the difference of reflection ratio at the two distinctive wavelengths, red(wavelength : 685nm) and near infra-red(wavelength: 830nm).

Shigehiko et al(1997) developed a vision system which can distinguish the ripened fruits from the unripened fruits and leaves by using the difference of color components of fruit image acquired by camera, and an end-effector that consists of suction pad and cutting device using rotating knife.

Ryu et al(1989) and Cho et al (1991) developed a 3-D position detecting system using the phase difference of two images acquired from two TV cameras. Chang et al (1993) developed an apple harvesting robot which can recognize and position the fruit even though it is covered by leaves and stalks by 30%, and fruit picking hand with 3 fingers which picks the fruit by eccentric rotation.

But, still there remains the need to lessen positioning error in case of harvesting overlapped fruits and the fruits partly covered by leaves and stalks, etc.

This research was performed to develop a vision system for tomato harvesting robot which can position the fruit more accurately 3-D positioning, even though the target tomato is overlapped and partly covered with leaves and stalks and the case when the target fruit is not on the center line of the lens of fixed camera.

MATERIALS AND METHOD

Consist of experimental system

The experimental system consists of visual device using stereo image processing and laser distance detector for detecting distance z axis, and 6 axis manipulator and controller for pan/tilt, and main computer for the data transmission and receiving. Figure 1 shows the schematic diagram of experimental system and table 1 is the specification of tomato harvesting robot

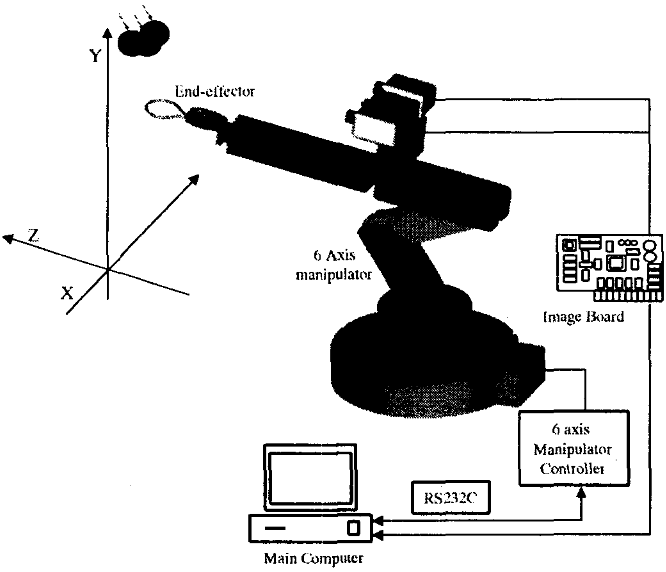


Fig. 1 Schematic diagram of the experimental system.

Table 1. Specification of tomato harvesting robot

Item	Specification	
Manipulator	Number of axis Repetition precision Workspace	6 joint ± 0.05mm Radius 708mm
Visual system	CCD camera(2set) Image board Laser detector	PULNIX TMC-74 Matrox Meteor- II Emitter 780nm Accuracy 2.5mm
Main computer	IBM Pentium- II	

Method of the 3-D Position Detecting

The visual system is composed of two CCD cameras for stereo image processing and laser distance detector to measure the depth from camera to the target tomatoes. Figure 2 shows the visual device. The CCD cameras and laser distance detector attached to the third axis of the manipulator and laser distance detector can be shot in the same direction of the optical axis of camera.

The first Method of the three dimensional position detection was stereo image processing technique(Gonzalez, 1992) using the phase difference of two images acquired from two CCD cameras, and the second method was the combination of two CCD cameras with pan/tilt mechanism which could decrease the positioning errors even though target tomatoes are not placed on the center of lens. Finally laser distance detector was added to the visual system to detect the target tomatoes which are partly covered by leaves and stalks.

Fig. 2. Picture of vision system.

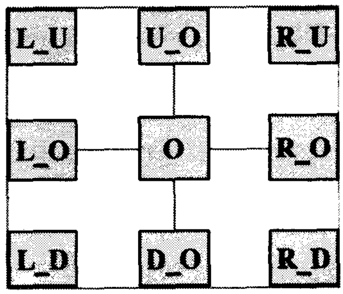


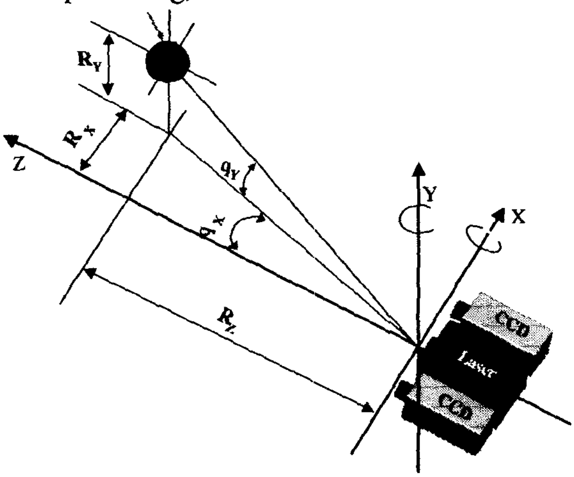
Fig 3. Position of tomatoes from lens.

Figure 3 shows the experimental positioning. Target tomatoes placed on the central direction(O), horizontal direction(L_O, R_O), vertical direction(U_O, D_O) and edge direction(L_U, R_U, L_D, R_D) from center of lens. In those various positioning, relationship between actual distance and measured distance of target tomatoes were analyzed.

Pan/tilt algorithm

When target tomatoes are partly covered with leaves and stalks, three dimensional position detecting errors were increased because reference point of input images of the two CCD cameras are different due to the differences in size and shape. So, laser distance detector was added to the visual system in order to reduce the position error of the depth.

Figure 4 shows method of the pan/tilt. At first step, using stereo image processing technique(Rafael c. Gonzalez. Digital Image Processing) three dimensional positions could be detected by the phase difference of two images acquired from two CCD cameras, next step, utilizing RX, RY, RZ, pan/tilt angle is calculated by equation (1) and (2). In order to pan/tilt, manipulator rotate to calculated angle which are θX, θY, Finally, after pan/tilting, laser distance detector shot the laser beam for detecting distance z axis and x, y axis distance detected by stereo image processing method using the phase difference of two images acquired from two CCD cameras



$$\theta_x = \tan^{-1}\left(\frac{R_x}{R_Z}\right) \quad \text{------------------}(1)$$

$$\theta_y = \tan^{-1}\left(\frac{R_y}{\sqrt{R_x^{2} + R_z^{2}}}\right) \quad \text{------}(2)$$

Fig 4. Schematic diagram of detection method of pan/tilt angle.

Flowchart of the pan/tilt

Figure 5 shows the process of the three dimensional position detection using two CCD cameras and pan· tilt mechanism which covers ± 15° working area.

First the manipulator is moved to -15° position in x axis and two cameras acquire images. If no ripe tomato is found, the manipulator moves in +5° step until it finds ripened tomato within +15° range.

If it finds ripe tomato, it calculates the position of the tomato in X, Y, Z axes by stereo image processing. Then using both the calculated position of the center of the target, it calculates the amount of pan/tilt angle needed to coincide the beam projection axis of the laser attached between two cameras with the calculated center position of the target.

After moving the manipulator's axis 1 and axis 3 exactly the same degree of angle as the pan/tilt angle calculated above, it measures the new Z position again. By combining this new Z position with the previously acquired X and Y positions, we get new X, Y, Z position of the target tomato.

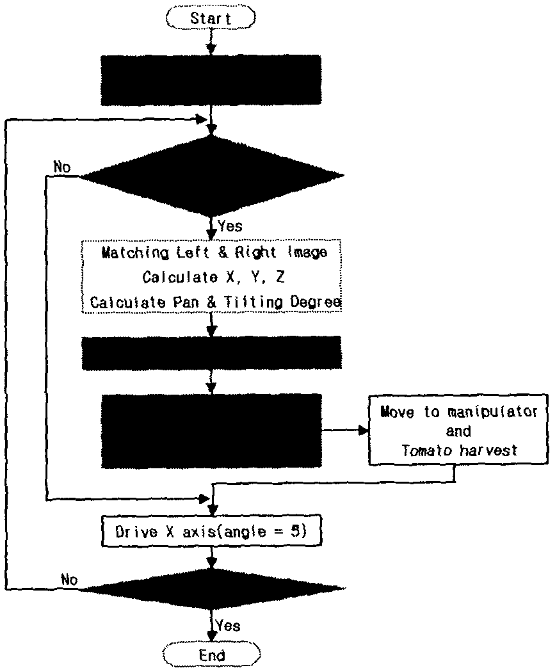


Fig 5. Flow chart of pan/tilt algorithm

RESULTS AND DISCUSSION

Position detecting with Fixed camera

Two cameras fixed to a position, each position focused on a target tomato were measured changing the position in horizontal and vertical direction, varying the distance from the center of the two lenses from 830mm to 1075mm by certain steps.

The positioning error between the actual position and measured position was, as shown in table 2, higher when it was positioned on edge (L_U, R_U, L_D, R_D), than when it was positioned on the center projection line of the two lenses. The maximum error of the latter position 38.3mm, about 4 times bigger than that of the previous case 8.8mm.

This result seems to be due to the difference of images acquired from the same target tomato. It could be because the more askew the target is from the center line, the bigger is the difference in the image.

Table 2. Result of position detection error by position of tomato from lens

Actual distance	Position detecting error(mm)								
	Center	Horizontal		Vertical		Edge			
	O	L_O	R_O	U_O	D_O	L_U	R_U	L_D	R_D
830	-0.4	7.8	13.0	10.7	11.0	14.5	20.0	14.0	16.1
900	4.2	6.7	17.9	16.1	11.9	14.4	29.3	12.8	20.5
955	6.1	8.0	32.9	13.7	15.6	15.6	28.0	10.3	29.0
1010	3.1	12.4	30.3	23.9	15.5	15.5	36.8	13.4	35.7
1075	8.8	13.4	27.4	16.9	11.1	23.9	38.3	18.0	28.6

Position detecting with pan/tilt procedure

For the tomatoes which are located in a position within 830~1075mm in Z axis direction, we measured the center of each tomato. Then, after we aligned the center projection line of two cameras with the center of a tomato by pan/tilt, the position of laser beam point was measured also. As a result, (as shown in picture 6,) the center of the two cameras

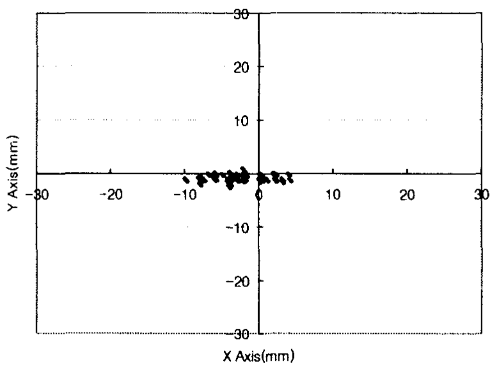


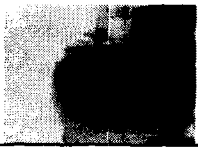
Fig. 6 Result of position detection error

was positioned close enough to the center of the target tomato; the maximum displacement error was within 10mm.

The Z component errors could also be within 10mm, even a tomato is not located in the center line of the lens, when the distance is measured after pan/tilt.

Meanwhile, when the position of tomatoes covered by leaves and stalks was measured, the positioning error become bigger due to the difference of the sizes of acquired images and the difference of covered portion when two cameras were used.

Table 3. Result of position detecting error

	Position detecting error(mm)		
			
840	8.9	35.9	65.5
895	1.7	32.9	59.5
970	1.9	29.2	56.5
1020	5.9	29.1	51.4
1070	6.9	34.0	53.9
1130	7.0	35.8	54.3

The stereo image processing technology combined with pan/tilt method was used on three variables; not covered, one side covered, and both sides covered case. When both sides were covered, the maximum error was increased to 65.5mm which is far bigger than that of uncovered case which has only 8.9mm, due to the deviation of center position of the two images for the same target.

Position detection combined pan/tilt with laser detector

When the target is not covered, it was possible to reduce the positioning error by pan-tilting method even if the target is positioned off the center line of the two lens. But when it is covered the positioning error was increased because the difference in the center position of the two images for the same target.

Also, by using the pan· tilting method with two cameras, the positioning error was considerably reduced compared to the use of two cameras only.

In picture 7, we showed the pre-view and post-view of pan/tilt to the left side, and the brightest point on the target tomato indicates the one pointed by the laser detector on the right side.

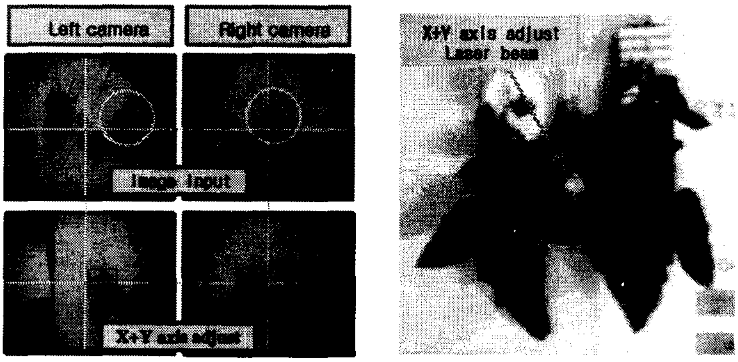


Fig. 7 Result of position detection

CONCLUSION

A three dimensional position detecting system combined with stereo image processing method with a laser distance detector was developed and tested to be adopted as machine vision system for tomato harvesting robot. The exact three-dimensional position of the target tomato can be detected by pan/tilt and three a laser detector even if same parts of the target tomato is covered with leaves and stalks.

The experimental system consists of a set of two CCD cameras, a frame grabber, a laser distance detector for detecting z axis position, 6 axis manipulator for pan/tilt and a controller.

Using the pan/tilt mechanism of a camera system, with the position of the target tomato not placed on the lens center, the deviation of detected position error were less than ± 10mm.

However, when it comes to positioning tomatoes covered with leaves and stalks, the position detection error was increased due to misleading images caused by the leaves and stalks.

In order to resolve this trouble a laser distance detector was added to the vision system, Which significantly reduced the position deviation resulting to position error less than 10mm in X, Y direction and 5mm in Z direction.

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