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Agricultural Robot with 8 Degrees of Freedom (I)

——Trial Manufacture of 8 DOF Manipulator——

Naoshi KONDO and Yasunori SHIBANO[a)]
(Division of Agricultural Infrastructure Development and Conservation)

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Introduction

Articulated robot for plants which grow in relative narrow area such as tomatoes and telescopic robot for plants whose canopies are big such as oranges have been investigated in Japan[1,3)]. Telescopic robot can arrive at an object in a short time by a simple calculation of joint angles of the manipulator, but lacks flexibility. However articulated robot has flexibility, the calculation for the control of the manipulator is complicated and requires long time. Farm working robot needs the big working area and more degrees of freedom than industrial robots, since agricultural objects are often hidden by obstacles such as leaves and stems.

In this report, 8 degrees of freedom manipulator which articulated manipulator was attached to telescopic manipulator end was made as a trial, and fruit approaching experiment and plant pulling experiment were investigated.

Experimental Device

Fig. 1 shows 8 degrees of freedom robot made as a trial, which a polar coordinates manipulator with 3 degrees of freedom and an articulated manipulator[4)] with 5 degrees of freedom were combined. The size of the robot was 2100 mm in length, 540 mm in width, 800 mm in height from ground to shoulder joint, and weighed 200 kg. Each actuator was DC motor, and telescopic arm moved straight by changing rotating directions of DC motor using rack and pinion.

Fig. 2 shows construction of the manipulator. Rotating angle of each joint, each arm length, and offset length are following.

$\theta_1 = -130^\circ \sim 130^\circ$
$\theta_2 = -40^\circ \sim 30^\circ$
$S_3 = 0 \sim 1000$ mm (Stroke)
$\theta_4 = -175^\circ \sim 175^\circ$
$\theta_5 = -65^\circ \sim 125^\circ$
$\theta_6 = -125^\circ \sim 145^\circ$
$\theta_7 = -155^\circ \sim 160^\circ$
$\theta_8 = 360^\circ$endless

$L_1 = 800$ mm (Offset length)
$L_2 = 0$ mm (Offset length)
$L_3 = 500$ mm (Offset length)
$L_4 = 0$ mm (Offset length)
$L_5 = 229$ mm (Arm length)
$L_6 = 229$ mm (Arm length)
$L_7 = 0$ mm (Offset length)
$L_8 = 130$ mm (Offset length)

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a) Division of Agricultural Technology of Integrated Land Use

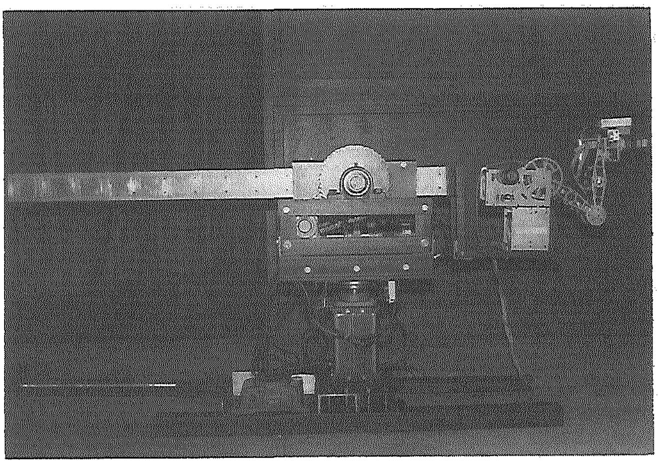

Fig. 1 Agricultural 8 degrees of freedom robot.

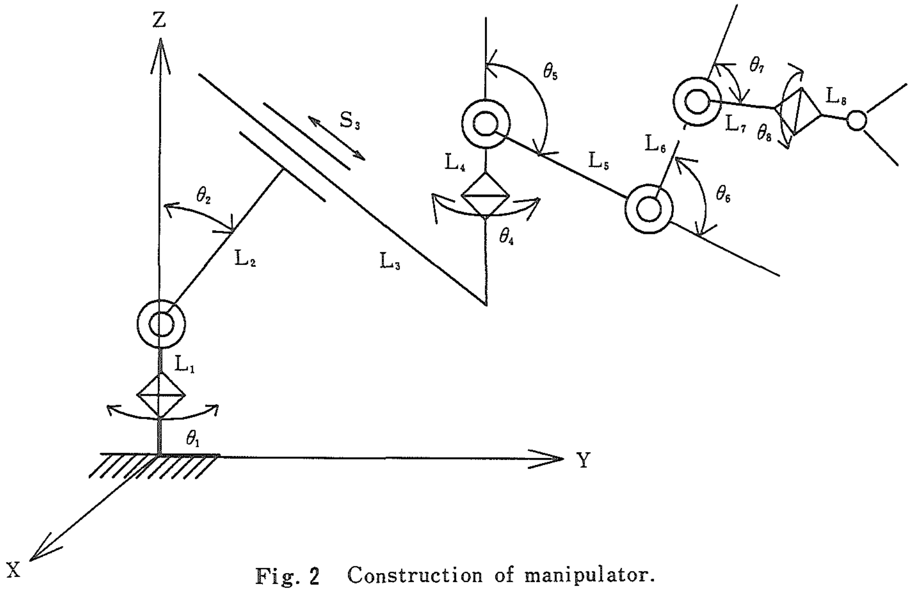

Fig. 2 Construction of manipulator.

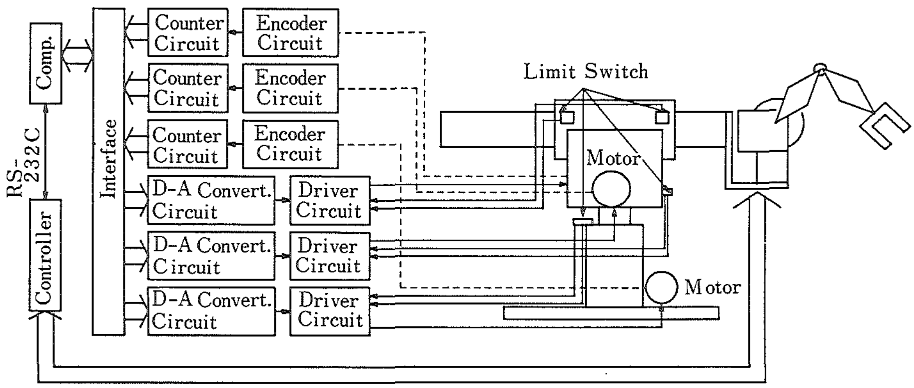

Fig. 3 Blockdiagram of drive circuit.

Fig. 3 shows blockdiagram of drive circuit of the manipulator. The polar coordinates manipulator was driven by using parallel interface of personal computer with 16 bit CPU. The three DC motors rotated in proportion to analog signals into which digital signals from the personal computer were converted by D-A converter. Each motor had an encoder whose output pulse was able to be counted by a counter circuit, and the displacement of each joint was obtained. The articulated manipulator was controlled using RS-232C by the controller[4] of

Table 1 Resolving power of joint

Motor No.	Joint	Encoder Pulse No.	Reduction Ratio Reduc. Gear	Sprocket	Resolving Power (° /pulse)
1	Waist	500	1 : 60	1 : 5	0.0024
2	Shoulder	1000	1 : 60	1 : 3	0.002
3	Arm	500	1 : 10	1 : 2	0.0163 (mm)
4	Waist	6	1 : 65.5	1 : 4	0.2290
5	Shoulder	6	1 : 65.5	1 : 8	0.1145
6	Elbow	6	1 : 65.5	1 : 8	0.1145
7	Wrist 1	6	1 : 65.5	1 : 8	0.1145
8	Wrist 2	24	1 : 12	1 : 4	0.3125
9	Hand	24	1 : 12		0.6※ (mm)

※Average Value

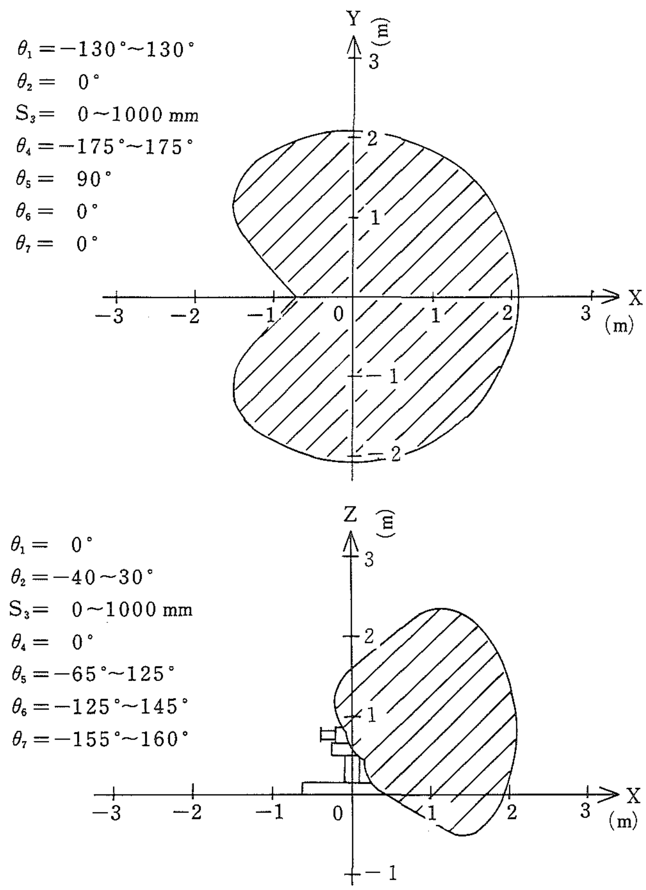

Fig. 4 Working area of manipulator.

the manipulator. Resolving power of each joint was shown as table 1. It was designed that resolving power of the joint of the polar coordinates manipulator was higher than that of the articulated manipulator in order to increase the accuracy of the manipulator end.

Fig. 4 shows working area of the manipulator end which was calculated by computer. It was observed that the manipulator end could reach in the semicircular area whose radius was about 2000 mm on X-Y plane, and that could reach at 2300 mm height from ground on X-Z plane. It was considered that this working area was large enough for management of fruit trees or thinning of plants.

The visual sensor whose picture element number was 244×244, image input time was 1/60 second, and image data was sent to memory of personal computer was attached to the articulated manipulator end, in order to be able to detect even objects which positioned far away or were hidden by obstacles.

Experimental Method

In this experiment, the visual sensor was not used, the manipulator took the postures for fruit harvesting and plant thinning using models of fruit and plant in the laboratory. Fig. 5 shows the flowchart of the fruit approaching experiment for harvesting. It was already reported fruits are so often hidden by obstacles such as leaves and stems that visible part of fruit was little from front side of tree and that was bigger from underside[2]. In this flowchart, the polar coordinates manipulator approached in the working area which the articulated manipulator could grasp fruit at first, the articulated manipulator took the posture for fruit harvesting avoiding the obstacles secondly. Fig. 6 shows the flowchart of the plant pulling experiment for thinning. In this flowchart, the articulated manipulator approached to the plant from upper side, not to bruise other plants, and pulled out a plant in the raising seedling box.

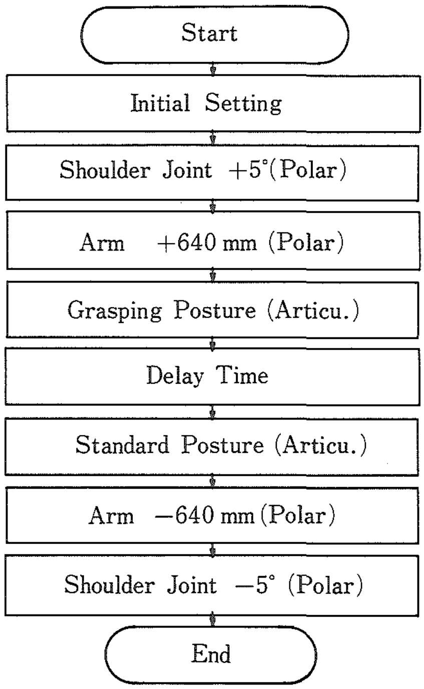

Fig. 5 Flowchart of fruit approaching experiment.

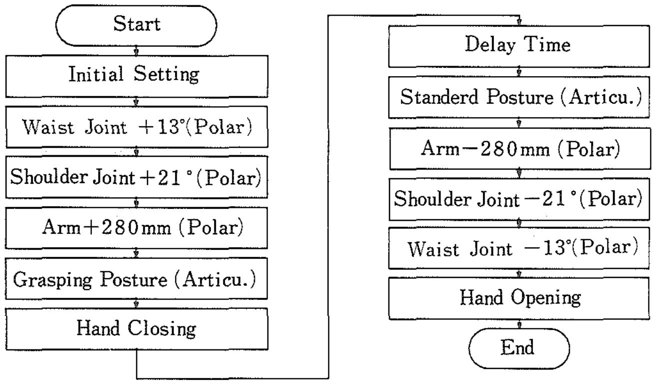

Fig. 6 Flowchart of plant pulling experiment.

Experimental Results and Consideration

Fig. 7 and 8 show the postures of the manipulator for fruit harvesting and for plant pulling in the experiments. From both figures, it was observed that the manipulator could approach

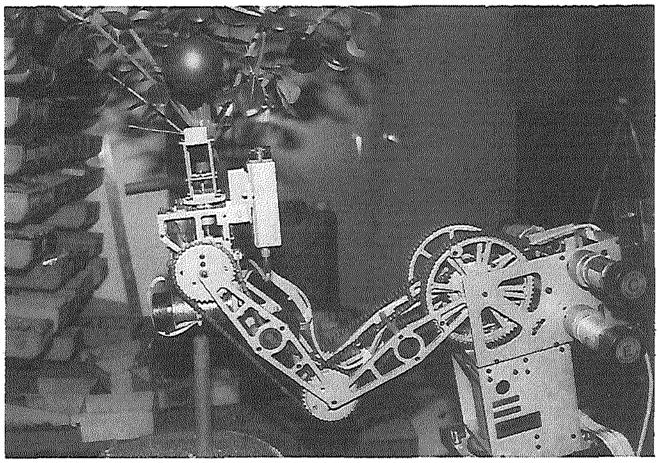

Fig. 7 Posture for fruit approaching.

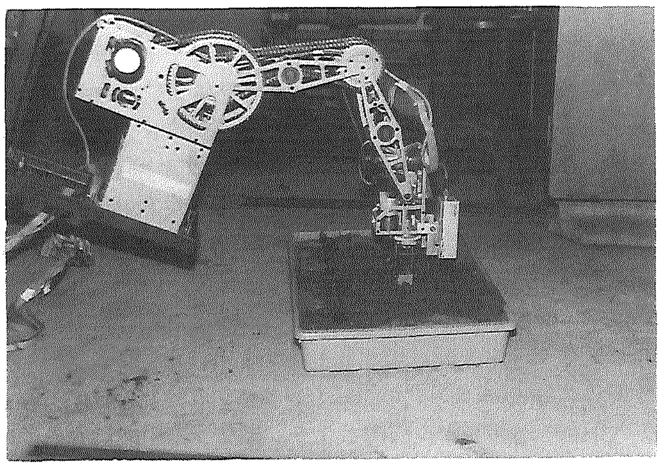

Fig. 8 Posture for plant pulling.

to the objects avoiding the obstacles because of the redundance, and that it could be used for many objects.

Summary

8 degrees of freedom manipulator which articulated manipulator and polar coordinates manipulator were combined was made as a trial. The size of the manipulator was 2100 mm in length, 540 mm in width, 800 mm in height from ground to shoulder joint, and weighed 200 kg. Fruit approaching experiment and plant pulling experiment were done in order to investigate the effectiveness of the redundant mechanism of the manipulator. From the results, it was observed that the manipulator could approach to the objects avoiding the obstacles because of the redundance, and that it could be used for many objects.

References

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農業用８自由度ロボットの研究（Ｉ）

――８自由度マニピュレータの試作――

近藤　直・芝野保徳[a]
（基盤整備学講座）

現在，農業用ロボットの研究が進められており，比較的狭い作業範囲の野菜類に対しては関節型が，柑橘類等の大きな樹冠を有するものには直動型のマニピュレータが報告されている。農作業においては，その作業範囲が広く，目的とする対象物が障害物の後方にある場合が少なくないため，比較的自由度の大きなマニピュレータが適すると考えられる．そこで本研究では，直動型マニピュレータ先端に関節型マニピュレータを取り付けた冗長自由度を有するマニピュレータを試作し，果実接近実験ならびに植物体の抜取り実験を模擬的に行った．

試作した８自由度ロボットは３自由度の直動型マニピュレータと５自由度の関節型マニピュレータを組み合わせて構成した．直動型マニピュレータはDCサーボモータにより回転運動をするウエスト部，ショルダー部，及びモータの回転運動をラックとピニオンで直線運動に換えられるアーム部から成る．アーム部の全長は1.5ｍでストロークは１ｍとした．関節型マニピュレータには市販のものを使用し，そのアーム部の全長は457 mmである．各モータは装着されているエンコーダで回転角度を知るようになっており，その制御には16ビットのパソコンを用い，直動型はパラレルインターフェイスで，関節型はRS-232Ｃで信号を入出力する．視覚部には，画素数244×244をもち，1/60秒で入力画像を行い，約0.4秒でパソコン内のメモリに画像データを転送できるセンサを用いた．

このロボットの手先の可動範囲はXY平面においては，直動型ウエスト部を中心としてマニピュレータの前方で半径約2000 mmの円内となる。またXZ平面においては，地上から約

a）農地生産力開発学講座

2300 mm の高さまで，及び地上では幅約 1500 mm の帯状の可動範囲となった．これは極座標マニピュレータの可動範囲に近く，間引き作業及び果樹管理作業等，種々の農作業に対して十分なものと考えられた．

このロボットを用いて果実の収穫，摘果作業を目的とした果実接近実験ならびに間引き，除草作業を目的とした抜取り実験を模擬的に行った．その結果，冗長性を有するマニピュレータのため，障害物を避けて対象物に容易に接近可能であり，汎用性も認められた．