Development of Harvesting Robot for Tomato Robot Competition 2022 and Its Evaluation

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Abstract

Agriculture is one of the most important industries for human food production. Recently, the number of farmers in Japan is decreasing, and the age of farmers is increasing. Therefore, the automation of agriculture using robot systems is highly required. The “Tomato Robot Competition” is held every year in Fukuoka, Japan, to arouse students’ interest in the field of agriculture, and to promote the development of agricultural automation technology by robot systems. In this paper, we introduce the developed tomato harvesting robot to participate in the “Tomato Robot Competition 2022”, and its harvesting performance evaluation. The developed tomato harvesting robot consists of 3 linear arms, an end-effector, a rail movement system, and an electronic system of communication and control. In the evaluation, the developed tomato harvesting robot took approximately 1.1 [min] to harvest a single tomato.

Keywords: Plant factories, Harvesting robot, Tomato robot competition 2022

1. Introduction

Agriculture is one of the most important industries for human food production. Recently, the number of farmers in Japan is decreasing, and the age of farmers is increasing [1]. Therefore, the automation of agriculture using robot systems is highly required.

Tomatoes are the most widely produced agricultural crop in the world [2], and one of the vegetables designated by Japan's Vegetable Production and Shipping Stabilization Law [3]. In countries developing agriculture well such as the Netherlands, "plant factories" that control the cultivation environment are also popular [4]. However, a series of operations such as plucking, leaf cutting, and harvesting must be performed in an environment where the facility is kept hot and humid, placing a heavy burden on the workers. Against this background, the “Tomato Robot Competition 2022”, a competition aimed at technological innovation related to robots living in harmony with nature and the introduction of robots into agricultural work, was held from November to December 2022 [5]. In this paper, we introduce the tomato harvesting robot that we developed to participate

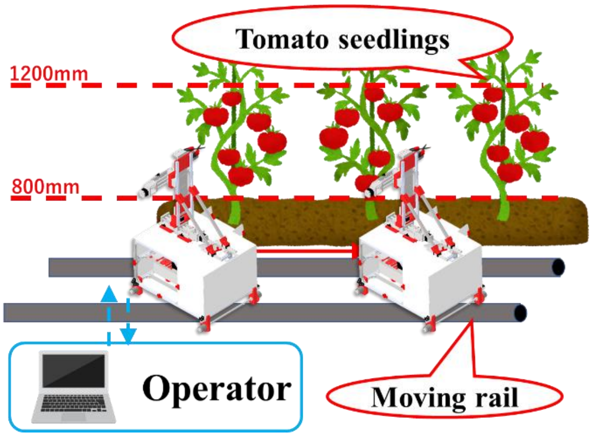

Fig. 1 Overview of tomato harvest work using a robot

in the “Tomato Robot Competition 2022”, and its harvesting performance evaluation.

2. Development of Harvesting robot

2.1. *Harvest strategy of this robot*

As shown in Figure 1, the robot is installed on top of a pipe in the plant factory where it operates. The robot is moved
to the top of the pipe and moved to the front of the tomatoes to be harvested. By repeating this operation, harvesting tomatoes growing at a height of 800 [mm] ~ 1200 [mm] from the ground is completed. Only tomatoes in the harvest stage of tomato fruit are harvested based on their color components.

2.2. *Design details of harvesting robot*

The tomato harvesting robot must satisfy the following four elements to be developed in this study.

(1) Operability
(2) Scalability
(3) Manageability
(4) Safety

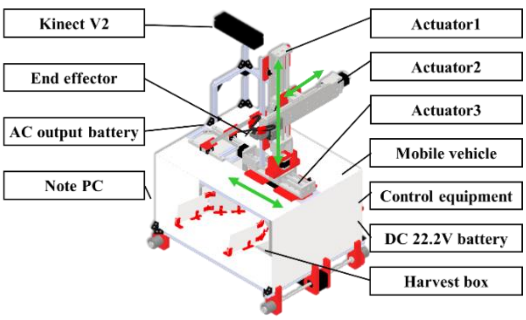

Fig. 2 Overview of developed harvesting robot

Regarding (1), one of the concepts of this machine is that it is easy to operate and can be operated by anyone. Therefore, As shown in Figure 2, an orthogonal arm was selected to allow the controller's sensory manipulation of the robot's arm.

Regarding (2), this is to ensure expandability when making improvements to the machine. The orthogonal type of arm was adopted from the viewpoint of scalability for automation. In addition, the robot's frame was also made of a 20 [mm] x 20 [mm] aluminum frame for expandability.

Regarding (3), This means that the robot can be easily maintained in the event of trouble. The control equipment, batteries, and harvesting box are all in one location for easy management. In addition, the robot is equipped with a cover that covers the entire outside for dust and drip-proofing, but the cover around the area where the control equipment is located can be opened and closed.

Regarding (4), The robot can be stopped by the user in case of an irregularity. The unit is equipped with an emergency stop button.

2.3. *Electrical and Controls Design*

The system configuration of the robot is shown in Figure 3. Two power sources were used a DC lithium polymer battery and an AC output battery. The AC output battery supplies power to the Kinect V2, the Wi-Fi router, and the Note PC, to which the Real sense is connected.

The lithium polymer battery is initially connected to the emergency stop. Next, supplies power to each device requiring a 22.2 [V] supply voltage. Also, the servo motor requires a 7.5 [V] power supply and the Arduino requires a 5 [V] power supply, so we use a DC/DC converter to step down the voltage.

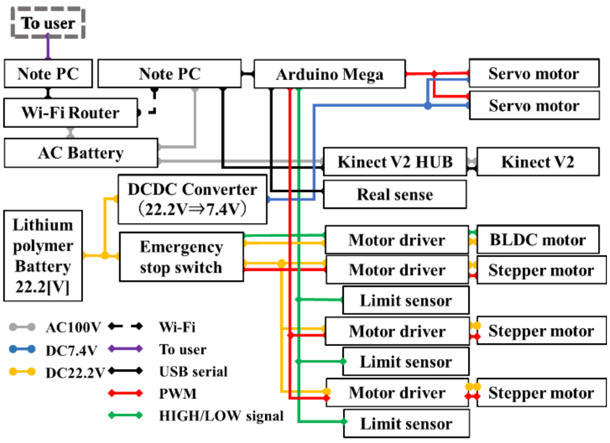

Fig. 3 Electrical and system configuration diagram

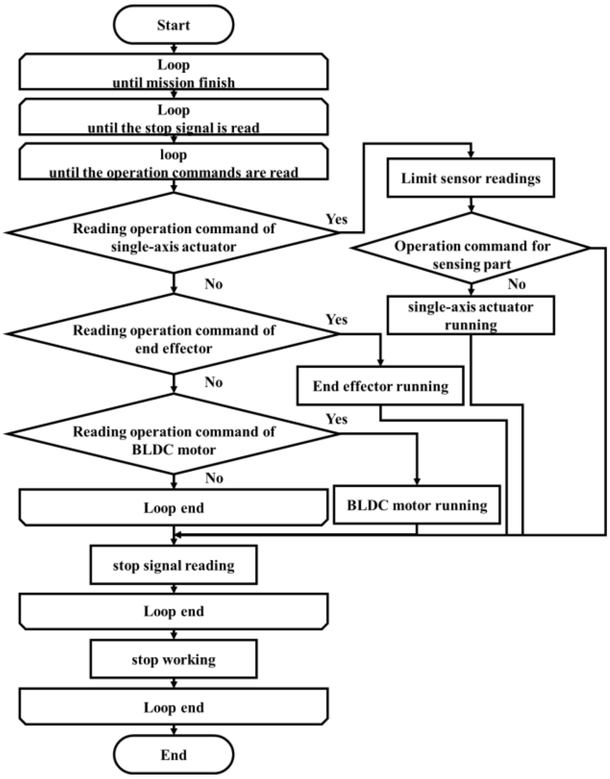

Fig. 4 Flowchart for tomato harvesting robot

Next, the system architecture is described. This robot operates by controlling motors and sensors through a remote desktop connection by Wi-Fi to a laptop PC equipped with the tomato robot. The moving cart is operated by a BLDC motor. The Cartesian arm is equipped with a motor driver, stepping motor, and limit sensors. The orthogonal arms are equipped with three single-axis actuators. The end effectors are operated by servo motors. These represent the gripping mechanism of the scissors and the rotation mechanism of the roll angle. All these motors are controlled by Arduino, a microcomputer that can handle PWM signals and HIGH/LOW signals.

2.3. *The control program of harvesting robot*

Figure 4 shows the operation program of the machine.
First, the motion signals for each of the single-axis actuators, end effectors, and BLDC motors are read. For the three single-axis actuators, after reading the motion commands, the machine reads whether the limit sensor of the single-axis actuator has detected a slider. If not detected, the actuator moves according to the motion signal, and if the motion signal is a 2-servo motor or BLDC motor, the actuator simply moves according to the motion command. After the motion, the motion stops when the stop signal is read. This sequence of motion continues to operate as a loop until the robot's power is turned off.

3. Evaluation experiment of developed Robot

We experiment to evaluate the performance of the developed robot. This evaluation was done in the same condition as the competition. In addition, ten people were harvested for accurate evaluation. Operators 1~5 are not experienced operators and operators 6~10 are experienced operators. Figure 5 shows the results by watching the actual operation, and Figure 6 shows the results by watching the sensor video.
When watching the actual operation, the success rate is 96.7% and the harvesting speed is 0.9 [min/piece].
When watching the sensor video, the success rate is 80.4% and the harvesting speed is 1.1 [min/piece].

4. Conclusion

In this paper, we describe the design and development of our robot and the evaluation of its harvesting performance. The results of the experiment show that the

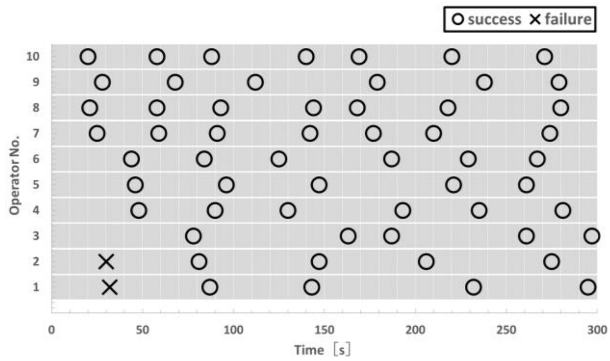

Fig. 5 Harvest results by watching the actual operation

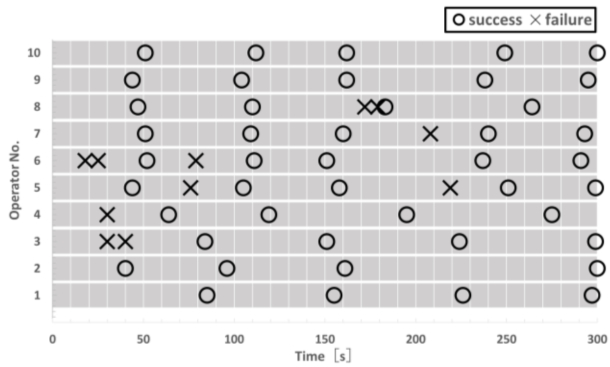

Fig. 6 Harvest results by watching the sensor video

success rate and harvesting speed decreased while watching the sensor images. Therefore, we should that the sensor mounting and the sensing system itself need to be improved.

In addition, the experienced operators had a slightly higher harvesting speed than the inexperienced operators. Although they are remotely operated now, autonomous robots are desirable for competition.

In the future, it is necessary to increase the operating speed and consider sensing for automation.

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5. Tomato Robot Competition 2022

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