Report on the 8th Tomato-Harvesting Competition toward Smart Agriculture

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Abstract

Tomato is one of the important fruit vegetables and most tomatoes are produced in the greenhouses, or large-scale farms, where the high temperature and humidity, and long harvest age force the farmer heavy works. To develop the tomato harvesting robot, many research issues exist such as manipulator design, end-effector design, collaborative behavior, artificial intelligence, motor control, image processing, target recognition and so on. With an aim to promote the automation of tomato harvesting, we have organized the tomato harvesting robot competition since 2014, and currently changed the competition field to the greenhouse in 2020. In this paper, we discuss the results of 8th tomato harvesting robot competition in 2021.

Keywords: Tomato-Harvesting-Robot Competition, End-effector, Mobile Mechanism

1. Introduction

According to statistical information by Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) [1], the agricultural workforce in 2020 is 1.4 million workers, which is 22.5% of 2015 in spite of world population increase. In addition, the rate of elder workers (over 65 years old) increased 4.9% to 69.8%. The decrease of the number of agricultural workers and their aging have become one of social problems in Japan, whose reasons are heavy work, knowledge transfer from experts to young workers, the large initial investment when starting farming, and a small income compared to the investment, etc.

Recently smart agriculture using AI, IoT, big data and robot technologies has been attracting attention, and it is expected to improve the agricultural works in efficiency and contribute to labor-saving by automated operations, parameterization and visualization of expert farmers and sharing. In the automation of agricultural work, research on agricultural harvesting robots has been actively carried out, e.g., Hayashi et al. developed a strawberry harvesting robot with obstacle avoidance control algorithm to approach the target fruit without damaging the neighboring fruits [2], Henten et al. developed an autonomous robot for removing unwanted cucumber leaves [3] and Lehnert et al. realized autonomous harvesting of sweet pepper using mobile robot with 6-DOF robot arm, end-effector and RGB-D camera[4].

We have been organizing the Tomato Harvesting Robot Competition since 2014 with the aim of developing agri-robots, arousing the interests of young researchers in robotics into agriculture, and giving back the developed technology to the agricultural field [5]. The competition is divided into two leagues, Junior league for outreach activities to junior and senior high school students and Senior league for actual harvesting demonstrations. In the junior league, each team develops a robot that harvested small tomatoes using LEGO Mindstorm. In the senior league, competitors demonstrate the harvesting performances of their developed robot(s) using tomato plants for commercial production. Fujinaga et al. also reports the mosaic image of tomato plants using IR and RGB-D images for estimation of maturity of tomato fruits, which are also developed through the competitions [6] [7].

In this paper, we report the results of the 6th Tomato-Harvesting-Robot Competition and discuss the regulation changes toward actual applications.

2. Smart Agriculture and Tomato-Harvesting-Robot Competition

2.1 Smart Agriculture

Smart agriculture is a new style of agriculture that utilizes robot technology and information and communication technology (ICT) to promote labor saving, precision, and high-quality production. By utilizing smart agriculture that makes full use of advanced technology, it is possible to overcome the issues in agricultural work, secure new farmers, and improve cultivation technology.

Japanese agriculture is facing a serious labor shortage due to the aging of individual farmers. It is required to support such hardships in Japanese agriculture by utilizing ICT. The smart agriculture is expected for labor saving and labor reduction of agricultural work.

The second issue is the transfer of cultivation technology to new farmers. In the old system, the knowledge is transferred in families or small groups. The shortage of human resources makes difficult to inherit expert knowledge in agriculture in the old fashion.

Japan's food self-sufficiency rate (calorie basis) was about 40% in FY2018, and imports far exceed domestic production. In order to increase the yield and increase the self-sufficiency rate in the face of the above-mentioned shortage of human resources, automation by IoT, AI and robots is indispensable for reliably growing agricultural products with a small number of workers. We are expecting to contribute Smart Agriculture through the Tomato-Harvesting-Competitions.

2.2 Tomato-Harvesting-Robot Competition

The Tomato-Harvesting-Robot competition started in 2014 and the 8th competition was held in winter of 2021, which consists of two leagues, the Senior League and the Junior League. The target competitors for Senior League are supposed to have and automated and self-contained robots, and the Junior League are for young students, where they make teams with 2 to 4 students and make a robot with LEGO Mindstorms or Spike, or their own mobile robots.

In the Senior League, each team developed one or two robots that harvests medium tomatoes (approximately 60 to 120 grams) provided by Hibikinada green farm Ltd..

Each team chooses one of two areas depending on mobility, the rail-style area assuming the operation in the greenhouse with rails or the free-style area assuming the outdoor cultivation.

The regulation is revised as shown on Table 1. From 2020, the place of senior league is changed to our Greenhouse(Fig.1) in our campus, Kitakyushu Research & Science Park. The field of free-style area is soil field of the greenfield. So that all teams are required to adapt the change of lighting condition depending on time and weather, which will make the image processing to adapt outdoor environment

Fig. 1 Overview of Greenhouse

Table 1 History of regulation revisio

N-th	Year	Rule & Changes
1	2014	Senior League started with 6 categories from T1 (manual operation) to T6 (autonomous) and 2 kinds of working fields (rail and artificial grass)in indoor field (Gymnastium). The black boards are set behind tomato plants.
2	2015	Senior: No rule change. Junior: Junior League started. Lego mindstorm is used for basic platform.
3	2016	Senior: Bump is placed in the center of grass field. Junior: No rule chage.
4	2017	No rule change.
5	2018	Senior: Slope is placed instead of Bump in the grass field. The black boards are removed. In scoring, success rate is added. Junior: Original arm made of stationery is allowed. Tomato box removed.
6	2019	No rule change.
7	2020	Senior: Video evaluation instaed of 1st and 2nd rounds. The cometition field is changed to the ourdoor experimental green house. The grass field is changed to the soil field. Junior: Online cometition in each school.

2.3 Competition site, Greenhouse in Our Campus

The greenhouse developed for smart agriculture is shown in Fig.2. The house size is 10m x 20m and the half area is designed for cultivation with soil and the other is for hydroponics. Currently, as agricultural IoT Sensors, temperature, moisture data, pH regular measurement of soil, regular measurement of temperature, humidity and illuminance in the greenhouse, photography of plants, have been implemented. As actuators for control air condition and soil condition, opening and closing the greenhouse walls, spraying mist, water supply control by solenoid valves, water circular system in hydroponics, the system for purification of rainwater and control of nutrients are under implementation.

Using the experimental house, we will encounter to various problems in agriculture. For example, recognition of green worms imitating the leaf vein, disease of plants, harvesting and so on. Transmitting data to cloud data base is also one research topics with limited communication.

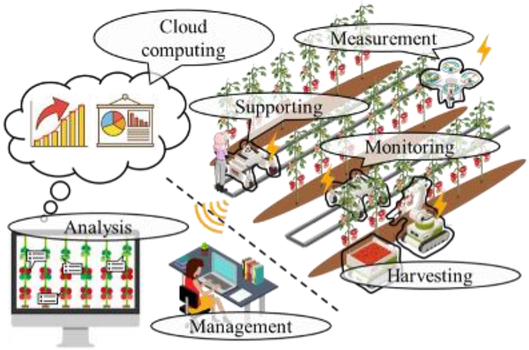

Fig.2 Overview and concept of the Greenhouse

2.4 Results

Table 2 shows the result of 9th competition. The winner team, HAYAHI-LAB (Fig.3)succeeded to harvest 18(=14+1+4) tomatoes in 10 min and the success rate was 72%. The second team (Fig.4) got 5 tomatoes and the rate is 40%. The speed of harvesting is getting faster and the success rate is improved.

Table 2 The results of the competition

Team	Tomato Condition					Damage to Stem (-5)	Harvest Rate	Points	Rank
	Get	Get & Unripe	Get & Dameages	Drop	Remain & Damages				
Hibikino-Toms	2	0	1	2	0	0	0.40	12.00	2
	3	0	2	2	0	0	0.43	23.43	
Tomastar	0	0	0	4	0	0	0.00	-8.00	
	0	0	0	0	0	0	0.00	0.00	
Mizurin	0	0	0	1	0	0	0.00	-2.00	
	1	0	0	5	0	0	0.17	-7.33	
SugarLab	3	1	3	2	0	1	0.33	17.67	3
	3	3	2	1	2	0	0.27	18.00	
HAYASHI-LAB	13	1	4	0	0	0	0.72	179.11	1
	10	1	2	2	1	0	0.63	109.00	
Iida Lab	2	0	1	0	2	0	0.40	12.00	
	1	0	1	0	3	0	0.20	-1.20	
HSRL-Tomato	0	0	0	0	0	0	0.00	0.00	
	0	0	0	0	0	0	0.00	0.00	
TOMASON	0	0	0	0	0	0	0.00	0.00	
	1	0	1	0	0	0	0.50	12.00	

Fig. 3 The winner Team HAYASHI-LAB

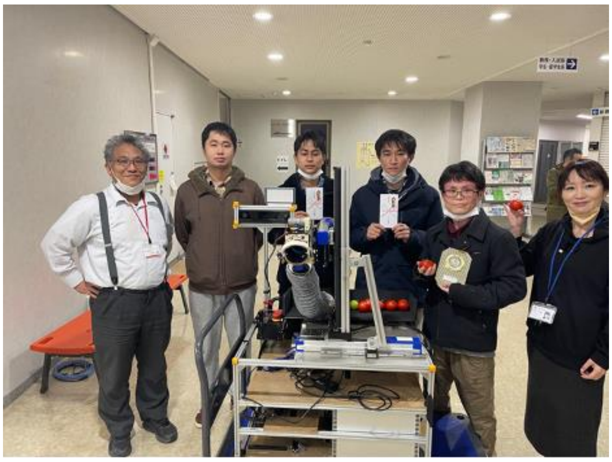

Fig. 4 The second team Hibikino-Toms

3. Conclusion

In this paper, we report on the 9th Tomato Robot Competition, which aimed at the social synthesis of robots. We also summarized the changes in the rules of the Senior League since the first competition. The operating environment was modified to be similar to that of a real farm, and the calculation method of the score was modified to aim at harvesting accurately. We have been working for experimental greenhouse. The agricultural IoT devices are implemented toward smart agriculture. The house system will include IoT sensors and actuators to control environment, robots for monitoring, harvesting, and transportation. Next regulation change will be usage and combination of IoT devices toward smart agriculture.

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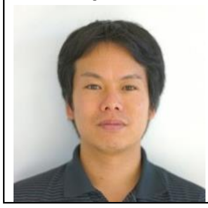

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