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Report on the 5th Tomato-harvesting Robot Competition

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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. In this paper, we report on the results of 5th tomato harvesting robot competition in 2018.

Keywords: robots for socio synthesis, robot competition and agriculture robot

1. Introduction

Recently, the aging and depopulation of famers grow worse in Japanese agriculture, as results the shortages of future famers and manpower become big problems. Ministry of Agriculture, Forestry and Fisheries of Japan reported that Japanese self-sufficiency ratio for food is about 40 percent, which is lowest level among developed countries. As one of solutions for the problems, the implementation of robot technology into the agriculture is expected.

Most of commercialized robots are for industry and robots for agriculture, forestry and fisheries are under developing, however, not commercialized yet. The reasons for the delay are cost-efficiency of the robotization, safety of the works using robots, difficulty of outdoor operations, and knowledge transfer problem from farmers to computer, etc. If we can overcome these difficulties and implement the robots into agricultural fields, robots can contribute to the laborsaving, improvement of production, production line automation. Also, the management of agricultural products such as quality, quantity, and condition of environment become possible and the smart-agriculture will be realized. Tomato is one of 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[1,2].

Several research results have been published though tomato harvesting competitions. For example, in mechanics designs and system designs, Yamaguchi and et., al., proposed about rotational plucking gripper for harvesting [3], B.Li and et., al. also proposed end effector design for harvesting[4], and Fujinaga and et., al. proposed system design about Tomato harvesting robot and software[5].

In this way, many new agricultural robot design methods and recognition algorithms have been born. One of the major goals of this tournament is to create new technological evolution and knowledge sharing through the tournament.

In this paper, we report on the results of 5th tomato harvesting robot competition in 2018.

2. Competition regulations

The tomato harvesting robot competition consists of two leagues which are he Senior League and the Junior League. The target competitors for Senior League are supposed to the team with automated and remote-controlled robots, and the Junior League are for high school or junior high school students who build robot using LEGO Mindstorm. In this section, competition regulations and new rules of both reargues will be introduced.

2.1. *Senior League*

The Senior League supposes that teams are not restricted to university nor company, just each team should have own tomato harvesting robot(s). Two kind of competition field are designed, the one is rail-style area and the another one is fee-style area as shown in Fig.1 and Fig.2. The rail-style area is designed to have the similar environment with the tomato factory with heat pipes for warming greenhouse. Free-style area is for the robots of open-field culture environment.

Fig.1 Free-style area[2]

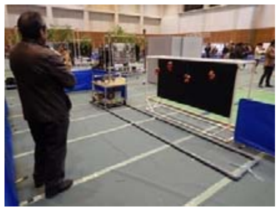

Fig.2 Rail-style area[2]

Fig.3 1st Stage [2]

Fig.4 2nd Stage [2]

Fig. 5 Final Stage [2]

Tomatoes are hanged on height from 800[mm] to 1200 [mm] referring to tomatoes arrangement of Hibikinada Saen Co., Ltd. Regarding the sizes of robot, the projected area of the robot to the ground is within the 800 × 800 mm^2 and no height limitation. For safety reason, the robots should have an emergency stop switch on the easy-to-find position. As the recommendations, the weight of the robot is <50 kg and the electric power of motor is <70 W/each.

The first stage is intended as the inspection of basic functions needed for tomato harvesting, so that single tomatoes are suspended as shown in Fig.3. The team succeeded to touch the tomato, moves to the second stage. In second stage, some sets of bunches of tomatoes are suspended as shown in Fig.4. The five high score teams go up to the final stage. The score is calculated based on the number of successfully harvested tomatoes and damages to tomatoes. Also, the unripe tomatoes are counted as the damaged tomatoes. Final score of second stage is the score multiplied the basic score and the coefficient decided by a combination of choice between the control method which are remotely and autonomous control and the areas which are the rail area and the free style area. In final stage, the robots harvest tomato from plant body as shown in Fig.5.

Table 1 The class number and coefficient at choosing remote control

Method of View	Directly		Indirectly	
Area	Rail	Free	Rail	Free
Number of Category	T1	T2	T3	T4
Coefficient C	1	2	2	4

Table 2 The class number and coefficient at choosing autonomous control

Area	Rail	Free
Number of Category	T5	T6
Coefficient C	8	16

The robots are classified mainly into two types, manual control and autonomous control, and the former robots are classified by whether the operator observes tomato directly or indirectly using cameras mounted on robots, and by robot locomotion whether the robot uses rail or not. Totally, the robots are categorized into six types depending on operation and locomotion method as shown in Tables 2 and 3. The success points of one-tomato-harvesting change depending on the robot category, e.g., the point of one-tomato-harvesting for T-1 is 2 × 1 = 2 points, and that of category T-6 is 2 × 8 = 16 points[2].

The 5th tournament, 4 rules are changed by organizing committee. At first, in free style section, we add the slope (height is 100 [mm] and slope distance is 900 [mm].) on the field. 4th competition, we added the step on the field. However, there was no development of robot design with rules with steps. Therefore, we changed step to slope. Second, In the tomato self, we put tomato and black board for recognizing tomato easily in image processing. In this year, the black board has been removed. Third, 4th competition, scores are evaluated as shown in Eq.(1)

$$P = C(2\alpha + \beta) - 2(\gamma + \delta) - \varepsilon \qquad (1)$$

where P is score, C is coefficient of magnification depending on selecting class as shown in Table 1 and 2, α is the number of tomatoes which is no damaged and correct color, β is the number of damaged tomatoes, γ is the number of drop tomatoes and γ is the number of damaged tomatoes which are not harvested. ε is a deducted point when robots damage stalks of tomato plants and the point is deducted in Final Stage. However, if the teams select high class such as T5 and T6, Total score P is almost not influenced from γ, δ and ε. This means that teams selected high class can get high score if robot damage tomatoes and drop tomatoes. In actual tomato factory, damaged tomatoes and drop tomatoes have no commercial value. However, this competition is aim to carefully dealing with tomatoes. Therefore, we proposed new equation for next competition as shown in Eq.(2).

$$\boldsymbol{P = \frac{\alpha}{\alpha+\beta+\gamma+\delta} C(2\alpha + \beta) - 2(\gamma + \delta) - \varepsilon} \qquad (2)$$

Equation (2) is employed harvest rate and if robot damage and drop tomatoes magnification C is decreased. At last, number of robots are not limited.

2.2. *Junior League*

In Junior League, the subject is to carry small size tomatoes to assigned positions. Students should develop the robot using LEGO Mindstorm with the functions such as line trace, color recognition, end-effector with mechanism design and motors with control, and their programming[1].

The basic specification for robot is that the size of the robot is within 300mm x 300mm on ground [2].Height is no limited. Students should develop the robot using LEGO Mindstorm. Competition subjects include Line Trace Challenge, Color Identify Challenge, Mechanism Design and Control Challenge and Object Detection Challenge.

In Line Trace Challenge, robots should detect white line in the competition area and move along the line using a color sensor. The robot starts from the starting point. In the middle of the course, the tomato harvesting field (harvest field) exists, where tomatoes are arranged. The robot must move to the harvest field in order to get the 6 tomatoes. In Color Identifying Challenge, robots should explore and recognize color signs in the middle of the course and the same color of tomatoes. As guidance to harvest field, red, yellow and blue lines are drawn in the field. It is necessary for the robots to detect guidance line by color sensor. The robot gets the tomatoes of the same color. Along the black line for line trace, each color is signed. The robot can move to the harvest field from the lone detecting the color. In Mechanism Design and Control Challenge, robot should manipulate tomatoes using manipulator and carry to the storage location. To pick up the tomato box by using a manipulator equipment which is made by each team, participants are expected to design and make a device to get tomatoes on their idea. The robot is required to store, transport and relocation depending on tomatoes in each color. After picking up the tomatoes, the robot should return to the course. Then, the robot carries the tomatoes to the specific storage location. In Object Detection Challenge, robots should detect a battery charging station and stop there. The 5th tournament, a rule are changed by organizing committee. 4th tournament, tomatoes were stored in a box called "tomato box". However, when using the tomato box, the robot could easily carry tomatoes, so it conveys that it was important to handle plant carefully. Therefore, we decided to use raw tomatoes and make the size irregular. We decided to encourage a new mechanical design by changing rules. And, some points have been changed by changing tomato harvesting rules. Details are given in the rule book [6]. Also, in order to treat the tomatoes carefully, a rule was added to deduct points if the tomatoes are damaged.

3. Results

Teams which could proceed to final stage are 5 teams including HAYASHI-LAB (Category T5, Kyushu Institute of Technology), Nagasaki GANBARANBA (Category T4, Nagasaki Institute of Applied Science), Taccary (Category T5, Kyushu Polytechnic college) and Nishikodai Robo Ken, NIT-LAB(Category T3,Nishinippon Institute of Technology). 1st place of rail-style division is HAYASHI-LAB, 2nd place is NishikodaiRoboKen and 3rd place NIT-LAB. In free style devision 1st place is Taccary and 2nd place is Nagasaki GANBARANBA, and 3rd are no eligible teams. Finally, Overall winner is HAYASHI-LAB (Table 3-5). In Junior League, number of the participated teams were 18 teams and the result is Table 6 and Table 7.

Table 3 Final result of the Senior League

Ranking	Team
Overall winner	HAYASHI-LAB
Overall runner-up	Taccary

Table 4 Result of rail-style division

Ranking	Team
1st place	HAYASHI-LAB
2nd place	NishikodaiRoboKen
3rd place	NIT-LAB

Table 5 Result of free-style division

Ranking	Team
1st place	Taccary
2nd place	Nagasaki GANBARANBA

Table 6 Result of rail-style division

Ranking	Team
1st place	NiAScience (High school attached Nagasaki Institute of Applied Science)
2nd place	Sponge pob (Hita Rinko High School)
3rd place	SORA (Hita Rinko High School)

Table 7 Special award

Ranking	Team
Best presentation award	J-Advance1 (Fukuoka Joto high school)
Technical award	J-Advance2 (Fukuoka Joto high school)
Special award	Kaho Total High school
Challenge award	Kako-1 go (Kashii Technical High School)

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