Tomato-Harvesting Robot Competition: Aims and Developed Robot of 6th Competitions

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Tomato-Harvesting Robot Competition: Aims and Developed Robot of 6th Competitions

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Abstract

In general, farm work is often hard work. In recent years, the number of farm laborers has been decreasing due to the aging of the workforce. Therefore, there is a need to automate agricultural work, and we are organizing a tomato harvesting robot competition to automate tomato harvesting. The competition includes a Junior Division for high school students and a Senior Division for college students. In this paper, we report on the results of 6th tomato harvesting robot competition.

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

1. Introduction

In recent years, the decline and aging of the agricultural workforce has become an issue. According to data[1] released by Japan's Ministry of Agriculture, Forestry and Fisheries, the number of agricultural workers in 2020 was 1,361,000, a decrease of 22.5% or 396,000 compared to the previous survey in 2015. In addition, the percentage of people aged 65 and above rose to 69.8%, up 4.9% from the previous survey. This is due to the fact that a large number of people quit farming due to old age, and securing the number of farmers is an issue. In recent years, in order to cope with the decreasing number of agricultural workers, there has been a lot of research and development of agricultural robots aimed at automating agricultural work. Among them, we have focused on tomatoes and have been holding tomato harvesting robot competitions since 2014. As the research of tomato harvesting robots in Japan, Kawamura et. al. developed a mobile robot with manipulator [2] and proposed the tomato harvesting method using image processing and visual feedback [3]. Kondo et. al. proposed the method to improve the success ratio of tomato harvesting and speed-up technique [4].

In this paper, we will report on the result of the 6th tomato harvesting robot competition.

2. Competition regulations

2.1. *Senior League*

In Senior League, 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. Free-style area is for the robots of general tomato fields in outdoor environment. In first stage, a tomato is suspended and the team is able to advance to the second stage when an end-effecter of the robot is able to touch the tomato. In second stage, a cluster of tomato is suspended. Teams compete against each other to see how many tomatoes they can harvest. The score is calculated using Eq. 1 below.

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

$$\boldsymbol{\eta = \frac{\alpha}{\alpha+\beta+\gamma+\delta}} \qquad (2)$$

, where P is score, C is coefficient of magnification depending on selecting class as shown in Table1, 2, $\alpha$is the number of tomatoes which is no damaged and correct color, β is the number of damaged tomatoes, $\gamma$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. Eq. 2 represents the harvest rate η. If multiple tomatoes are harvested but dropped or damaged, the final score will be less. In final stage, the robots harvest tomato from plant body. In addition, some farms do not actually have rails, in which case the road surface in the vicinity of the tomato plants has a slope. Starting from the 5th competition, we have installed a slope in the freestyle area to try to replicate the harvesting conditions of an actual farm.

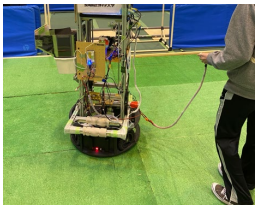

Fig.1 Free-style area

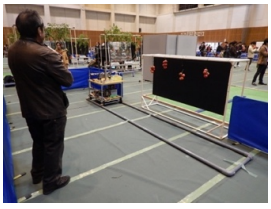

Fig.2 Rail-style area

Fig. 3 A slope set up in the freestyle area.

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

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 [5]. The basic specification for robot is that the size of the robot is within 300mm x 300mm on ground [5].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 black 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. Until the 4th Tomato Harvesting Robot Competition, the tomatoes were stored in a transparent box called "Tomato Box" beforehand, but from the 5th competition, the tomatoes were placed in a fresh state. Therefore, more careful handling of tomatoes is needed when the robot manipulates and transports

them.

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 as shown Fig.4. 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.

In addition to the above rules, we have added a new rule to handle tomatoes with care. Tomatoes are a food. Tomatoes are a food product, and if they are handled improperly in this competition, they will not be scored for storage points. The procedure for checking tomatoes in the competition and the criteria for judging when tomatoes are not handled properly are as follows:

1. A representative of each team member must check the tomatoes for blemishes before trials.
2. After the trials, all tomatoes must be checked for scratches by the referee and one team member. If there is any objection, one team member and the organizing committee chairman and vice chairman will discuss the matter.

Criteria for improper handling of tomatoes

1. if the liquid inside the tomato has been released to the outside
2. if the tomato is damaged in such a way that the inside of the tomato is visible
3. tomatoes are clearly dented from their pre-race condition
4. tomatoes are being transported in contact with the floor
5. if it is determined that the tomatoes have not been handled in a manner other than the above criteria

By adding the above rules, the goal was to instill in the competitors the awareness of handling tomatoes with care when carrying the actual product.

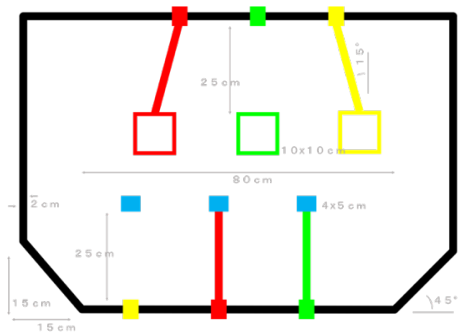

Fig.4 Robot Jr. League competition Field

3. Result of 6th tomato harvesting robot competition

The results of the competition of Senior League are shown in Table 3. The Senior League has revised its rules since the 5th competition, including changes to the scoring equation and the addition of slopes to the freestyle area. The equation is shown in Eq. 1, which introduces the concept of harvest rate, where dropping tomatoes and scratching tomatoes have a significant impact on the score. For practical use, the robot needs to harvest more tomatoes within a certain time frame. Therefore, it is desirable for the robot to work for the entire 10 minutes of the competition, but many teams quit the competition halfway through for fear of losing the harvest rate. As for the slope, many people said that it would be difficult to control the robot because it would slide down the slope without control.

The results of the competition of Junior League are shown in Table 4. The 6th competition was the second competition after the rules were revised to require the teams to harvest and transport fresh tomatoes. In the previous year, some teams damaged the tomatoes, but in this year's competition, there was some ingenuity in handling the tomatoes with care, and the students were able to instill an awareness of the importance of handling raw plants through their crafts.

Overall, the competition scores improved from the previous year, and one team was able to harvest and transport all the tomatoes in one week. Therefore, it would be better to make some rule changes for the next competition based on the competition held this time (since it is a high school competition, we will not change

the basic base, but will consider some additional elements).

Finally, some teams commented that it was difficult to make tomatoes of a consistent size. Lastly, some teams commented that it was difficult because the size of the tomatoes was not consistent. This may be a result of the fact that the purpose of the competition, which is to encourage ingenuity in the devices and algorithms due to the inconsistent environment of handling natural objects, was not well understood. I felt that it was necessary to create a mechanism in the regulations and website to appeal the purpose of this competition, that it is not only about winning and losing as a competition, but also about developing the ability to cope with nature

Table 3 Result of Senior League

Ranking	Team
Overall winner and 1st place of rail-style division	Hibikino-Toms (Kyushu Inst. Of Tech.)
Overall runner-up and 2nd place of rail-style division	Syuga-Lab (Nagasaki Inst. Of Applied Science

Table 4 Result of Junior League

Rankin	Team
1st Place	Tangokinasu (Fukuoka Joto High School)
2nd Place	Double Lycopin (Fukuoka Joto High School)
3rd Place	NiASience Ver.2 (Nagasaki Sogo Fuzoku High School)
Special Award	
Best Presentation Award	G-Advance (Fukuoka Joto Highschool)
Perfect Award	Tangokinasu (Fukuoka Joto High School)
Special Judges Award	Kako Tomato Curry (Kashii Technical High school)
Idea Award	Revolutionary (Fukuoka Joto High School)
Challenge Award	SyokugyoMochi (National institute of Technology, Kitakyushu college)

4. Conclutions

In this paper, Tomato robot competition for robot socio-synthesis was introduced. The tomato harvesting robot competition has two leagues which are Senior League and Junior League. In Junior League, number of the participated teams were 24 teams. In Senior League, number of participated team 9 team. In this competition, concept of carefully dealing with tomatoes will be employed.

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