Tomato Harvesting Robot Competiton

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***Abstract*—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 farmers heavy works. With an aim to promote the automation of tomato harvesting, we have organized the tomato harvesting robot competition. In this paper, we report on the results of tomato harvesting robot competition.**

Keywords—component; formatting; style; styling; insert (key words)

I. Introduction

In Japanese agriculture, the aging and depopulation of farmers grow worse, as the results the shortages of future farmers 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 farmers heavy works. In Holland, the various technologies are introduced, and high productivity is achieved more than Japanese farms.

As the research of tomato harvesting robots in Japan, Kawamura et. al. developed a mobile robot with manipulator[1] and proposed the tomato harvesting method using image processing and visual feedback[2][3]. Kondo et. al. proposed the method to improve the success ratio of tomato harvesting and speed-up technique[4][5]. Ota et. al. proposed the path planning method to pick up tomato [6].

With an aim to promote the automation of tomato harvesting, we have organized the tomato harvesting robot competition. In this paper, we report on the results of tomato harvesting robot competition.

II. Competition Regulations

The tomato harvesting robot competition consists of two leagues, the Senior League and the Junior League. The target competitors for Senior League are supposed to be the teams with automated robots, and the Junior League are for high school or junior high school students, whom are asked to build robots with LEGO Mindstorm.

A. Senior League

The Senior League supposes that teams composed of undergraduate, graduate students or developers join the competition with their tomato harvesting robots, and compete the accuracy and speed of tomato harvesting. The two kinds of competition field are designed, the one is called the rail-style area and another is the free-style area as shown in Fig. 1.

The rail-style area is designed to have the similar environment with the large-scale tomato factory where pairs of pipes are arranged on the ground to control the temperature of the greenhouse. And the pairs of pipe are also used as the rails for the platform trucks on which the workers sit down, harvest and carry tomatoes. The diameter of pipes is 50 mm and the distance between pipes is 600 mm. The position of tomato is always adjusted between 800 to 1200 mm heights as the tomato plants are growing up.

The free-style area is for the robots of general tomato fields in outdoor environment. Currently, artificial grasses are put on it with the sizes of 3600 x 3600 mm instead of soils. The setting of tomato position is the same with the rail-style area.

The required specification of tomato harvesting robot is shown in Table 1. The projected area of the robot on the ground is within the 800 x 800 mm square including a box for storing tomatoes, and no height limitation. The robots should have an emergency stop switch on the easy-to-find location of robots. As recommendations, the weight of the robot is less than 50 kg and the electric power of each motor is less than 70 W.

The robots are classified mainly 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 6 types depend on operation and locomotion method as shown in Table 1. The success points of one tomato harvesting change, e.g., the point of one tomato harvesting for the robot of category (1): manual control, direct tomato observation, rail-type is one point, and that of category (6): autonomous control, free-type is eight points.

The senior league consists of three stages as shown in Fig.2. In first stage, the basic function of the robot is evaluated whether the robot can move, have a manipulator and an end-effector, and recognize tomato. Single tomatoes are hanged from a bar and the robot that can touch a tomato proceeds to the second stage.

In the second stage, the robot harvests a tomato from a tomato cluster. The teams compete the scores and numbers of tomato harvested successfully. If the robot gives damage to tomato, get minus point, and the damage to tomato plant is big minus points. And the target tomatoes should be redder than the reference tomato indicated by the committee. The five highest score team are selected to the final stage. In final stage, the robots harvest tomato from plant body as shown in Fig. 3.

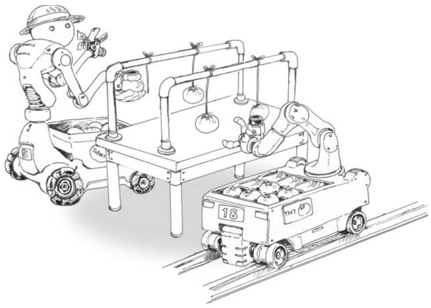
TABLE I. SPECIFICATIONS OF ROBOT

Requirement	Max. Size	W:800mm D:800mm No height limitation
	Safety	Emergency Stop Switch
Recommend	Max. Weight	Max. 50kg
	Max. Motor Power	Max. 70W each

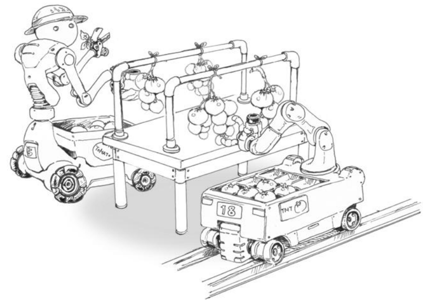
TABLE II. ROBOT CLASSIFICATION BY OPERATION METHODS

Robot Control	Manual				Autonomous	
Operator Manipulation	Direct Observation of Tomato		Indirect Observation of Tomato		Start and Stop commands	
Mode of Locomotion	Rail-type	Free-type	Rail-type	Free-type	Rail-type	Free-type
Category	(1)	(2)	(3)	(4)	(5)	(6)

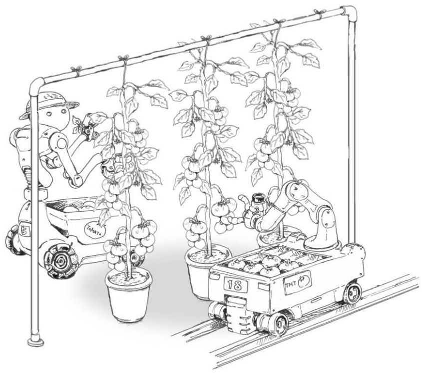
FIG. 1. THE COMPETITION FIELDS, LEFT: THE RAIL-STYLE, RIGHT: THE FREE-STYLE.



(A) FIRST STAGE: PICK UP SIGLE TOMATO



(B) SECOND STAGE: PICK UP A TOMATO FROM TOMATO CLUSTER



(C) FINAL STAGE: PICK UP A TOMATO FROM TOMATO PLANT

FIG. 2 THE THREE STAGES OF THE SENIOR LEAGUE.

FIG. 3 THE OVERVIEW OF THE FINAL STAGES OF THE SENIOR LEAGUE.

Result of the senior league

The 2nd Tomato Harvesting Robot Competition was held in Kitakyushu, Dec. 20th-21st 2015. The numbers of participated teams was 9 in the first competition and 14 in the second. The final teams in the 2nd competition are “GANBARANBA” (category (4), Nagasaki Inst. of Applied Science, Fig. 4), “HAYASHI-LAB” (category (6), Kyushu Institute of Technology, KIT), “KARITORITAI” (category (1), KIT), “JSK Seminar” (category (4), Univ. of Tokyo) and “Team SS” (category (4), others). The robots in category (4) are remotely controlled and equipped one or two end-effectors for holding and harvesting a tomato. The robot “HAYASHI-LAB” shown in Fig. 7 is designed for the category (6), where the robot is autonomous and moves in the free-style area. The robot “KARITOEITAI” is the robot for category (1) and remotely controlled by the operator with observing tomatoes directly, shown in Fig.8.

As the result of this competition, the winner is HAYASHI-LAB, the second place is Team SS and the third place is “JSK Seminar. In additionally, as special award, the dream award was given to “JSK Tomato Robot Project” and the Hibikinada Green Farm award to “HAYAHI-LAB” from the Hibikinada Green Farm. The robot “JSK Tomato Robot project” was an autonomous robot as shown in Fig.11.

The result of competition on senior category

Ranking	Name of team	Score
First Place	HAYADHI-LAB	64
Second Place	Team SS	52
Third Place	JSK Seminar	44

Fig. 4 The robot of “GANBARABA”.

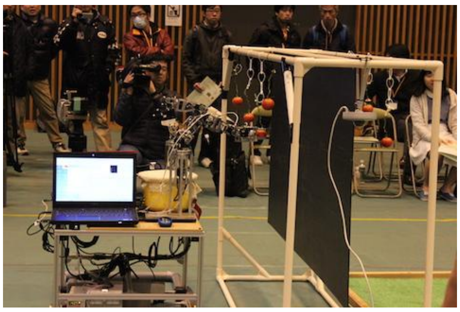


Fig. 5 The robot “HAYASHI-LAB”.

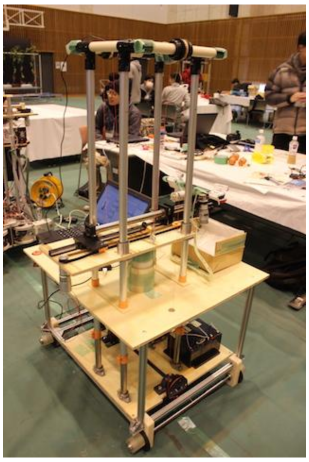


Fig. 6 The robot “KARITORITAI”

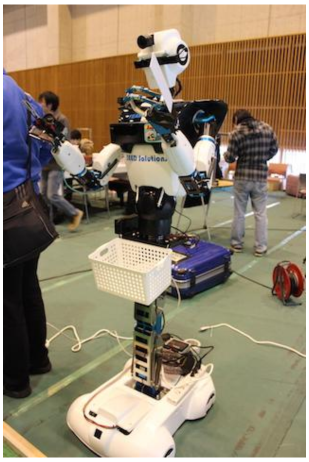


Fig. 7 The robot “JSK Seminar”

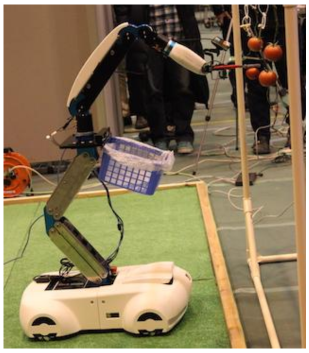


Fig. 8 The robot of “Team SS”

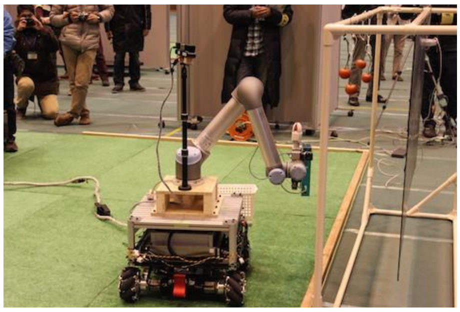


Fig. 9 T the robot of “JSK Tomato Robot Project”

B. Junior League

Figure 10 shows the competition concept of tomato robot Junior League competition. In the competition, we have selected the subjects to model an autonomous transport system of tomatoes harvesting, where the subjects of Junior League are such as the transport and sorting of the harvested tomatoes.

Competition subjects are shown below.

Line Trace challenges: Detecting the white course line (course line) in the competition area, to move along the line.

Color Identifying challenges: To explore and recognize color signs in the middle of course and the same color of three boxed tomatoes (tomato box).

Mechanism design and control: Using manipulator mechanism for tomato boxes, and stores it in the later carrying a tomato box to the storage location.

Object detection: Detects battery charging station and stop.

Each team consists of 3 or 4 students and makes a robot using LEGO Mindstorms EV3. Also robot programing is needed to automate the transport and sorting work.

The basic specification for robot is that the sizes of the robot are within 300 x 300 [mm] on the ground. If the robot has manipulation parts causing the shape changes of the robot, the folded robot size is regarded as the robot size.

Scoring

Competition time: In the competition, time limit is set to 10 minutes. As follows, we describe the detail of challenges:

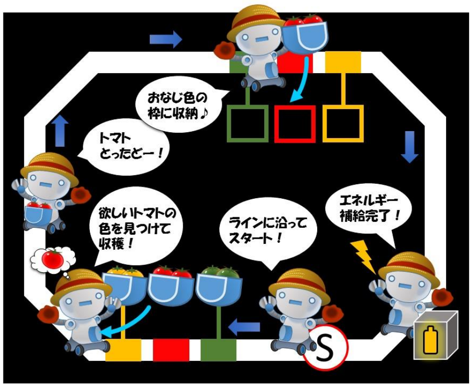


Fig. 10 The concept in Junior League.

Line Trace: The robot starts from the starting point. The robot must moves along the white course line using the color sensor. In the middle of the course, the tomato-box-harvesting field (harvest field) exists where Tomato boxes are arranged. The robot must move to the harvest field in order to get the tomato boxes.

Color discrimination: As for guidance to harvest field, red, yellow and green lines are drawn for guidance. It is necessary for the robots to detect guidance lines by the color sensor. After detection, the robot gets the same color of the tomato box. Along the line with the sign of the same color, the robot can move to the harvest field and get the tomato box.

Mechanism design and control: To pick up the tomato box by using a manipulator equipment (a mechanism for self-made by each team, such as a robot arm), participants are expected to design and make a device to get a tomato box on their own idea. The robot is required to store, transport and relocation depending on tomato box colors. After picking up the box, the robot are to return to the course line. Then, the robot carries the box to the specific storage location of the tomato box (following storage location). On the track line, the robot should follow the sign corresponding to each color which means the storage location.

Object detection: After putting he tomato boxes in the storage location, the robot should return to the original course line. Finally, the robot goes the charging station (fake). The charging station is installed at the position with the certain distance away from the course line, so that the robot must find the stop position by the distance measuring sensor. The robot is asked to stay the charging position more than 3 seconds.

Goal conditions: The robot continues the above tasks until he gets all tomato box on the course and carry to the storage location. Finally, it should stop the robot at the stopping position of the charging station front. Then, it is certified as a goal by sound cues of mission completion in sound. However, if the robot is not able to carry and storage all of tomato boxes, it is recognized as a goal if ring the above sound.

Score points are set in each task. Score has been set in the Additional system. Show a score system below.

1. move 100 points / lap
(However, up to a maximum of 300 points)
※ Additional and move to the tomato box harvest field
2. harvesting the tomato box
There is the guiding line: 100 points x 2
Guidance No line: 200 points x 1
3. store the tomato box
There is the guiding line: 100 points x 2
No guidance line: 200 points x 1
4. use of the charging station: 100 points / lap
(However, up to a maximum of 200 points)
1. goal to: 500 points

Bonus point
(A) if the goal to complete transportation tomato box three in the first lap: +500 points
(B) If the tomato box three was the goal to transport completed in the second lap: +200 points
Presentation point: 200 points

The stay on the charging station is allowed only once per lap. The robot becomes illegal if run reverse in the course line. The participants can change the program or hardware whenever the robot has troubles within the time limit. However, if the participants make adjustments or rewrite of the program during the competition, the robot should start from the starting position. The obtained point is not reset if once got. Using the above rules, the team can get the score as shown in Table 4.

TABLE V. SUMMARY OF SCORE OF JR. COMPETITION

Presentation is carried out in 2 minutes, it is assessed by the two judges.

Rule number	Presentation point	Task points						remarks
		1st lap		2nd lap		3rd lap		
		No goal	Goal	No goal	Goal	No goal	goal	
1		100	100	200	200	300	300	100 pt / lap
2		400	400	400	400	400	400	Get all tomato boxes (400 points)
3		400	400	400	400	400	400	Storage tomato boxes (400 points)
4		100	200	200	200	200	200	100 pt / lap
5		0	500	0	500	0	500	Sound a goal / 500 point
(a)		0	500	0	0	0	0	Finish all tasks in fist lap
(b)		0	0	0	200	0	0	Finishi all tasks in second lap
-	200	200	200	200	200	200	200	Presentation point
Total	200	1200	2200	1400	2100	1500	2000	Maximum point at retire or time up or goal
		600	1100	700	1050	750	1000	Maximum point if change the program

A) Competition schedule plan

The Junior League is held firstly, so that we had a pre-training lesson to one month prior to the competition to applicant. We were planning a lecture such as harvest landscape for Hibikinada vegetable garden Co. Ltd. and basic programming knowledge involved in the production of the robot in the pre-training sessions. The robot design and production of in competition, guidance by graduate students support no experience students for developing a robot system.

Competition has become a schedule of three days. In the morning of the first day, construction of the competitions venue, tomato of the carry-in, and so on. Tours of Hibikinada vegetable garden in order to understand the actual scene from the afternoon were planning. In the tour, the participation of the participants of the senior division and junior division, the introduction of such as tomato plants and cultivation method of the current has been carried out.

From the morning of the second day to start the production of the competition robot by each participating team. It was published and for the first time detailed the competition rules at this point. They have done an attempt to fill the difference between the environment and experience of each team by issuing the idea on the day.

In the morning of the third day is aimed at the exchange of technology made a presentation of each team and your robot production. Third day of the competition from the afternoon was ranking by either of the highest scoring twice trials.

TABLE II. RESULT OF JR. COMPETITION.

Team	1st trial	2nd trial
Kokura South high. G	1300	1300
Oita Tech. high A	1200	1500
Oita Tech. high B	1400	1400
OitaTech. high C	1600	1200
Tsurusaki Tech. high	300	300
Fukuoka Daiichi high	700	1300
Hokuchiku high A	1300	1100
Hokuchiku high B	800	1000
Hokuchiku high C	1300	1500
Hokuchiku high D	300	500
Ano Jr. high A	500	300
Ano Jr. high B	1400	800
Yahata high	800	600
KTEC	1000	700
Okayama shoka high	1200	1100
Kokura South high B	600	800

B) Competition result of Junior Division

Junior division, there were 16 teams of entry. High school team 14 team and the junior high school team was attended by 2 teams. In Table VI shows the results in the competition. All of the team made a presentation, it has succeeded in the production of the robot. Moreover, all teams have succeeded in some missions. The winning team can create programs for all tasks.Fig.12 shows overview of the real fields. And, Figs. 13-14 show view of the competition.

III. SUMMARY

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 farmers heavy works. With an aim to promote the automation of tomato harvesting, we had organized the first and second tomato harvesting robot competition. We hope that the competition promote the development and research on the agricultural robotics.

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