Compulsory Game based Robot Contest for Embedded System Development Education

Harumi Watanabe

Tokai University

Tokyo, Japan

harumi@wing.ncc.u-tokai.ac.jp

Mikiko Sato

Tokai University

Tokyo, Japan

mikiko.sato@tokai.ac.jp

Masafumi Miwa

Tokushima University

Tokushima, Japan

miw@tokushima-u.ac.jp

Makoto Imamura

Tokai University

Tokyo, Japan

imamura@tsc.u-tokai.ac.jp

Shintaro Hosoi

Change Vision, Inc.

Fukui, Japan

shintaro.hosoi@change-vision.com

Nobuhiko Ogura

Tokyo City University

Tokyo, Japan

ogura@tcu.ac.jp

Hiroyuki Nakamura

Kyushu University

Fukuoka, Japan

nakamura@qito.kyushu-u.ac.jp

Kenji Hisazumi

Kyushu University

Fukuoka, Japan

nel@slrc.kyushu-u.ac.jp

ABSTRACT

This paper proposes a compulsory game based robot contest involving embedded system development lectures. Both undergraduate and graduate computer science students participate in this contest. For such students, the embedded system development is not easy to learn. Because, the development needs to cover a wide range of knowledge in a variety of fields, including software, electronics, and control theory. Robot system development is an attractive subject for students and comprises various technologies that are similar to practical embedded systems. Namely, robot system development is useful for learning embedded system development. However, in single themed contests, we cannot evaluate the learning level of the students, and they cannot easy to understand how to construct a robot. To overcome this problem, we propose a compulsory game based robot contest. The compulsory games consist of fundamental techniques for developing robot systems and involves straightforward procedures for evaluating student learning level. Additionally, we intended for students to learn how to construct a robot system by solving the compulsory games in a step-by-step fashion. In this paper, we propose four compulsory games and evaluate the methods of this contest by examining its results.

CCS Concepts

- Social and professional topics → Computing education
- Computer systems organization → Robotics

Keywords

Embedded system development; education; robotics; project-based learning

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1. INTRODUCTION

Recently, various robot contests have become popular in a global context, because robot development is an attractive subject for many students, and is well-known for the useful educational materials [1,2]. For the past fourteen years, we have also been organizing a robot contest called *Embedded System Symposium Robot Challenge* (ESS-RC) for graduate and undergraduate engineering students.

Additionally, it has become easier to learn embedded system programming because of various educational robots, such as LEGO and robot cleaners [3-8]. Moreover, graphical programming languages have become popular for use with educational robots [5,9,10]. Because of its simplicity, robot programming has also been adopted in elementary schools [5,9,10]. However, for students studying to become engineers, embedded system development is not easy to learn. Because, the subject needs to cover a wide range of knowledge and skills in software, electronics, and control theory.

To obtain these skills, students need to be highly motivated. Additionally, relevant educational materials are required to cover these fields. Robot system development is an attractive subject for students and comprises various technologies that are similar to practical embedded systems. As mentioned in several related works [7,11,12,13,14,15], we believe robot system development is useful for learning embedded system development.

However, in single themed robot contests, such as NHK Robocon [16], we cannot evaluate the learning level of students, and students cannot easily understand how to construct a robot. To overcome this problem, we propose a compulsory game based robot contest involving lectures. The compulsory games consist of fundamental techniques for developing robot systems and involved straightforward processes for evaluating student learning levels. Additionally, we intend for students to learn how to construct a robot system by solving the compulsory games in a step-by-step fashion. In this paper, we introduce four of these

compulsory games and evaluate the methods of this contest by examining its results.

The remainder of this paper is organized as follows. Section 2 describes ESS-RC. Section 3 proposes the compulsory games. Section 4 evaluates the method of the contest and section 5 discusses whether the contest method solved the problems. Finally, section 6 concludes this paper.

Table 1. Spring School

	(1) Smart mobile robot competition	(2) Rover trial competition
20 May		
09:00-09:30	Opening and course guidance. Lecture 1: Ability to discover and solve problems with PBL learning for improving practical and research skills.	
09:30-09:50	Lecture 2: Relationship between general theory of system development and the profession of embedded software.	
09:50-10:35	Lecture 3: Trends and characteristics of development technologies in embedded systems.	
10:45-12:00	Lecture 4: Introduction to control theory.	
13:00-16:30	Exercise 1: Robot control exercise for iRobot Create2.	Exercise 2: Robot control exercise for Zumo.
16:30-17:00	Short presentation on industry–university collaboration.	
21 May		
09:00-14:00	Exercise 3: System development methodology.	Exercise 4: Basic measurement and implementation of embedded systems.
14:00-16:00	Exercise 5: Project management using Scrum.	
16:00-17:00	Closing.	
22-26 May	Practicing mini PBL exercise at home universities.	
24 May	Intermediate presentation of exercise progress.	
27 May	Final presentation of exercise results.	

Table 2. Summer School

11 August	
13:20-13:30	Opening
13:30-15:30	Compulsory games
16:00-16:30	Main game (Auto-Cruising Game)
17:00-17:15	Short talk for Poster
17:20-20:00	Poster
12 August	
09:30-10:45	Keynote 1: Big data and AI in Era of Industrial 4.0
10:50-12:05	Keynote 2: System Control with Machine Learning and AI
13:00-14:50	Student Workshop (for reflecting the contest)
15:00-15:50	Presentation of Workshop

Figure 1. SCRUM Project Management

2. ESS ROBOT CHALLENGE

The section describes our robot contest called Embedded System Symposium Robot Challenge (ESS-RC). Section 2.1 clarifies the educational goals, background, and schedule. Section 2.2 illustrates the main game of the contest.

2.1 Outline

The goal for ESS-RC is to provide an education of embedded system development. The contest is supported by *Information Processing Society Japan* (IPSJ) and enPiT, which is an educational project of *Ministry of Education, Culture, Sports, Science and Technology-Japan* (MEXT).

In 2016, the enPiT project began its second season. Accordingly, for ESS-RC 2017, we renewed the educational materials robot and the contest theme. Until now, the main theme has been the auto-cruising airship, the auto-vacuuming robot, and the multi-copter. The new robot is relatively small and is equipped with a camera. The detail illustrates in Section 2.2.

The educational periods of ESS-RC consist of Spring School, Summer School, and supplementary lectures. During Spring School, we provide lectures for fundamental knowledge of robot developments as shown in Table 1. Namely, we teach project management, as well as embedded software design, robot programming, and control theory. Figure 1 shows one scene in the SCRUM project management exercise, which is a framework for developing and sustaining complex products [17]. Through this management exercise, students can divide the contest games into small issues and goals. As a result of this lecture and exercise, we expect that students will become to understand how to construct the main game by using the compulsory games. Related works [13,15] applied SCRUM to project management in the PBL. In particular, the curriculum of [15] is similar to ours.

Summer School consists of the contest involving compulsory games, a poster session, two keynote speeches, and a student workshop, as shown in Table 2. In the poster session of the first day, students explain the features of the system and the development of the contest robot. The contest score includes the results of evaluating the poster. In the student workshop on the second day, students reflect on the development. The group of the workshop is organized as mixed Universities. Because students of all teams aim to the same goal, they develop friendly relations with one another, despite their different fields and university affiliations.

2.2 Auto-Cruising Game

The auto-cruising game is the main game of ESS-RC. The final goal of this game is to learn the fundamental technologies for modern embedded systems, such as IoT. In a few years, we plan to create a subject of ESS-RC involving those technologies. This year's contest is the first step toward the final goal. Therefore, we consider that a robot requires comprising some sensors and communication functions, as follows.

Figure 2 depicts the auto-cruising game. The robot is equipped with a camera, a three-axis acceleration sensor, a magnetic sensor, a three-axis gyro sensor, and a line-tracing sensor. The robot traces a route from its starting place on the map to the goal. While running, the robot distinguishes some AR-markers and adapts its behavior based on the markers' instructions. In ESS-RC, the teams compete to determine whose robot is faster and whose robot correctly follows the instructions given by the AR-markers.

Additionally, students explain the robot's behavior at runtime as shown in Figure 3.

Figure 2 Main Game: Auto-Cruising Game

Figure 3 View of Robot behavior

Figure 4 Compulsory game: Rotate robot

3. COMPULSORY GAME

This section proposes the compulsory games of ESS-RC. Previously mentioned, the compulsory games contribute the following issues: (1) identify learning level and (2) students learn how to construct a robot system in a step-by-step fashion. Thus, the compulsory games are fundamental technologies for building a robot system used in the main game. In the following, we illustrate the four compulsory games.

Figure 5 Compulsory Game: Line Trace

Figure 6 Compulsory game: AR-Marker

3.1 Spin Turn

This game aims to evaluate whether students identify quantities of robot behavior. Figure 4 shows the game. The issue of this game is as follows:

In a 20cm square area, a robot must rotate 180 degrees counterclockwise by the spin turn. Continuously, the robot rotates clockwise, counterclockwise, clockwise, and counterclockwise. When switching direction, the robot must stop over 3 seconds.

This game evaluates the running time and the angle of the gap between the goal and the robot's final stopping position. To accomplish this issue, students need to measure the behavior of the robot and identify the quantities required for movement.

3.2 Line Trace

This game aims to evaluate the student learning level of fundamental control theory. Figure 5 shows the game. The issue of this game is as follows:

A robot traces by the double black lines: the course distance is 2 m, the line width is 1 cm, the width between lines is 10 cm, and the course does not contain gaps.

This game evaluates running time and whether the behavior is smooth. To accomplish this issue, students adopt a fundamental control theory, such as PID. If students have never used any of the control theories, the robot will vibrate or easily stray off the course.

Table 3. Result of the games

Compulsory Game		Team			
		A	B	C	D
Spin Turn	Time		35	30	33
	Degree		20	25	180
Line Trace	Time	42	38	20	23
	Stray off	0	1	0	0
Maze	Time	48			47
	Obstacles	0			1
AR-Marker	Time				
	Distance				

3.3 Maze

This game aims to enable the consideration of algorithms. The course field of this game is same as the main game of Figure 1. The issue of this game is as follows:

In the game field, there are a start point, a goal point, and some obstacles. A robot must run from the start point to the goal point avoiding obstacles.

This game evaluates running time, whether the robot reaches the goal, and the number of times it avoids obstacles. If students desire the robot to run speedily, they need to consider some algorithms.

3.4 AR-Marker

This game aims to combine multiple knowledge. Figure 6 shows the game. The issue of this game is as follows.

While moving in 1 m square area, a robot must discover three AR markers and convey the position.

This game evaluates running time, the kinds of markers, and the distance of the gap between the marker position and the position information. To accomplish this issue, students need to combine communication and AR-marker algorithms.

4. EVALUATION

This section illustrates the results of the compulsory games' evaluation for considering whether the compulsory game based contest is adequate.

Seventy-eight students participated in the Spring School program, and their fields were computer science and control mechanics. The students were divided into 19 groups, with each group having three or five students. In Summer School, thirty-eight students participated, and four teams joined the contest involving the compulsory games. In Table 3, the numbers in each column indicate the results of the compulsory games as followed by the evaluation method explained in Section 3. In the following, we consider these results:

(1) Spin turn: Three teams gained scores. We consider that the reason for this is that students had experience with a similar exercise during the Spring School period.

(2) Line trace: All teams gained good points. Because line trace games are very popular for learning robot programming, some students had experience with line trace games before ESS-RC, while others easily obtained the necessary algorithms from informative websites.

(3) Maze: Two teams gained scores. The reason for this is that other teams exceeded the time limit. During the contest, students were required to finish all games within five minutes.

(4) AR-marker: All teams failed. After the contest, we found that AR-markers could not be technically identified. Outside of the contest, one team was able to identify the AR-marker as shown in Figure 3. However, this team could not distinguish the position of the AR-marker.

5. DISCUSSION

Previously mentioned, we invoked two issues for single themed contests. Firstly, we cannot evaluate the learning level of students. Secondly, students cannot easily understand how to construct a robot. In this section, we discuss whether the contest method contributes to the issues based on the results detailed in Section 4.

Reflecting on the game of 14 years ago, we had not yet adopted compulsory games in the contests. In those contests, we evaluated the behaviors exhibited in one game that was similarly constructed to the main game mentioned in section 2.2. The scoring method was designed around whether an airship was able to reach a certain height, move to a specific position, and then land in the goal position. Those contests had two significant problems. First, judges could not identify whether students adopted theories to their systems. Even if an airship reached the required height, the behavior could have been coincidental. Secondly, the contest game, such as the main game, was too complicated and expansive for students. If students did not divide the game program into smaller components, they were not able to obtain scores. Indeed, several teams did not achieve any scores at all.

As shown in Table 3, each team in our most recent contest was able to gain a type of score. Regarding the first problem of previous contests, we considered how to exclude coincidental behavior when constructing the compulsory game. For example, in the spin turn game, a robot was required to continue in the same motion five times, as mentioned in Section 3.1. Therefore, we considered that the scores in Table 3 were indicative of learning level. We regarded that all teams had checked whether they reached their own goals. Regarding the second problem, compulsory game programs that excluded the AR-marker game were simple and a suitable size for learning. Thus, all teams were challenged in the compulsory game according to their level of understanding.

So far, we have mentioned the advantages of the compulsory based contest. The rest of this section describes the disadvantages we must reflect on. Firstly, none of the teams were able to obtain a score in the AR-marker game. With our experience, we had considered that many students did not achieve the learning level of understanding the functional decomposition design. To solve this problem, we created the AR-marker game. Through the inquiry of students, we became aware that many of them lacked an understanding of the interruption handling. Additionally, this game system was hardly fit for use as a compulsory game because it was highly compounded with the AR-marker, the communication functions, and the position calculation by sensors. We should have divided this game into smaller issues. Thus, we should add the issue of interruption handling and divide the game into smaller issues in the next version of ESS-RC.

Secondly, the teams that joined the contest were small in size. As mentioned in Section 4, only 38 students participated in Summer School, while 78 students participated in Spring School. We

reflect that we may not have explicitly presented the learning roadmap for the main game.

6. CONCLUSION

In this paper, we proposed a compulsory game based robot contest to learn embedded system development. The compulsory games aimed to solve the following problems. First, we cannot evaluate the learning level of students. Secondly, students cannot easily understand how to construct a robot. We provided the compulsory games for students to learn the fundamental techniques of the main game that is the auto-cruising game. The compulsory games consisted of the spin turn, the line trace, the maze, and the AR-marker game. We believe that the compulsory games relevantly contribute to these problems. However, we also discovered issues, as described Section 5.

In future work, we will define the skills and the achievement goals for the total education of ESS-RC. Additionally, we will clarify the relationship between the lectures in Spring School and the compulsory games in Summer School by providing a learning roadmap. Furthermore, to provide the seamless learning stages, we will add some new compulsory games and improve the current games.

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