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EDUCATIONAL EFFECTIVENESS OF ROBOT CONTEST FOR STUDENTS IN DESIGN EDUCATION

Atsushi MITANI
School of Design, Sapporo City University, Japan

ABSTRACT
Robot contest gives a technical challenge opportunity to students studying robotics and mechatronics technology. In such contests, robot structure and function must be designed to complete specific tasks as quick and accurate as possible. Robot-Triathlon contest has been provided for university students in Hokkaido, Japan. The contest competes the time getting arrived at the goal, and presents four prizes, robot design, technical, idea, and poster, depending on the vote of audience and committee members.
My laboratory has joined in the Robot-Triathlon contest as the only team from university of design education and participants are required to consider both robot function and aesthetic appeals. This means that robot contest participants are required to have skill and knowledge about functional design and programming for robot controller as well as appearance design for aesthetic appeal. Though our curriculum in my University provides lectures and practical training classes mainly targeted for design expressions and proposals, few robot programming and function design classes have been provided. To participate in such a robot contest as Robot-Triathlon is a valuable opportunity for students in product design education because they can learn how to make their robots work in real world. Several robot designs for the Robot-Triathlon contest were introduced. The design process was almost the same as general products. Function design and programming were supported by the author. Evaluating these robots from viewpoint of both aesthetic and functional, I discussed the educational effectiveness of robot contest for students in design education.

Keywords: Robot Contest, Robot Design, 3D-CAD, Rapid Prototyping, Design Process.

1 INTRODUCTION

Robot contest gives a technical challenge opportunity to students studying robotics and mechatronics technology. The robot contests provide specific tasks that robots must complete using an automatic control system with sensor, actuator, and processor. Contest participants must design robot structure and function to complete these given tasks as quick and accurate as possible. The annual Robot-Triathlon contest, started from 2001, is a kind of robot contest of autonomous mobile robot for university students in Hokkaido region, Japan. The robot contest consists of three areas: (a) a line tracing area, (b) a wandering forest area, and (c) a replacing object work area. Robots compete the time getting arrived at the goal, and four prizes, robot design, technical, idea, and poster, depending on the vote of audience and committee members.
My laboratory has joined in Robot-Triathlon contest as the only team from university of design education. Our robots have competed in the contest from 2008 and several robots won the design prize or poster prize. I always ask students participating in this contest to design a robot pursuing aesthetic appeal maximally with basic functions to complete tasks. This means that they are required to have skills and knowledge about functional design and programming for robot controller as well as external design for aesthetic appeal in order to develop effective robots for this contest.
Though our curriculum in my university provides lectures and practical training classes mainly targeted for design expressions and proposals, few robot programming and function design classes have been provided. Participating in such a robot contest as Robot-Triathlon is a valuable opportunity for students in product design education because they can learn how to make their robots work in real world.
We can find previous works regarding educational effectiveness of robot contest. Ami[1] said that it would be useful for students in technical education to design and fabricate a robot to complete specific

target, because they will work at a production company in the future. Hanajima[2] considered a robot contest suitable for introductory education in engineering. Students can learn to complete such a given task as the line-trace [3] and the inverted pendulum [4] using some educational tools. These tools are suitable for learning feedback controller using sensors and A/D converters. However, they have not evaluated the effectiveness for students in design education.

Robot-Triathlon is a robot contest for introductory engineering education because a standard robot kit is available and beginners including students in design education can develop a effective robot easily to achieve specific tasks in the contest.

Three robot design won a design prize in Robot-Triathlon contest are introduced. The design process was almost the same as general products. Function design and programming supported by the author. Evaluating these robots from viewpoint of both aesthetic and functional, I discussed the educational effectiveness of robot contest for students in design education.

2 ROBOT-TRIATHLON CONTEST

Robot-Triathlon contest [5] has started from 2001 and university students in Hokkaido region, Japan. Any students, regardless of educational field, can participate in the contest as an individual or a member of team. Autonomous mobile robots compete for time completing a course with three areas: (1) a line tracing area, in which robot must move along with black coloured line by detecting it using light sensors, (2) a wandering forest area, in which robot must pass through keeping it from colliding cylindrical obstacles, and (3) a replacing object work area, in which robot must pick up a positioned object and take it to a designated place and put it. A standard robot kit (Umezawa Musen Denki) is produced for the contest. The kit consists of two motors with gear box, two tires, a set of infrared sensor to detect black line, a distance sensor to detect obstacles, a circuit board with a H8-3664 microprocessor board to control robots, and an acrylic resin board to develop a robot chassis. Soldering wires to connect among a circuit board and peripherals such as sensor and motor, and assembling each part and component to the chassis, an autonomous mobile robot can be obtained. A sample C program is available and robot can move forward and back, rotate, trace a black coloured line, and detect an obstacle after arranging it according to robot chassis design such as wheelbase and tread, sensor position and sensitivity. A kit based autonomous mobile robot, therefore, can complete the line tracing area and the wandering forest area.

The contest competes the time getting reached at a goal line. Mission complete time takes penalty and bonus into account, and a robot recorded the shortest mission complete time wins the contest. Penalty will be given when a robot or a player violates the contest rule and bonus will be given by performance in a replacing object work area.

Whole trial time is set at 4 minutes and the timer stops when a robot reaches the replacing object work area. In order to complete the task in the replacing object work area, additional functions, in some case s robot arm, must be embedded into the robot to handle an object. This means that each team can set own target according to technical level, for example, a rookie team will usually struggle to reach a goal line without any function for the replacing object work area, and a skilful team will consider how to complete the replacing object work area as well as consider how the robot can reach at the goal line as fast as possible.

The contest presents another four awards: robot design, technical, idea, and poster, depending on the vote of audience and committee members. For the vote, each team shows a A3 paper size poster to introduce a robot structure, function, and consciousness. And presentation opportunity for 1 minute is given for each team to appeal robot excellence.

3 DESIGN EDUCATION CURRICULUM

Design educational curriculum is different from engineering education. It includes some knowledge and skill to support student design a robot but it is difficult to complete an effective robot. Design education curriculum in my University was evaluated from the viewpoint of essential knowledge and skill to complete an effective robot to solve given tasks, comparing with typical engineering education. Table 1 shows the comparison of engineering and design education regarding knowledge and skill for developing a robot. The symbol 'Δ' indicates the class includes a part of relevant knowledge and skill. Term "class (grade) in design education" indicates the class name and grade it opens in my University, and classes in bold font are offered by the author.

"Prototype Simulation I" class offers the fundamental of rapid prototyping (RP), and students can acquire how to develop a mock-up of new electronic device based on CAD/CAM and RP. Using SolidWorks 3D-CAD software, a 3D model of new device is developed. The STL formatted 3D model is sent to Modeller Player CAM software, and the mock-up model is fabricated using MDX-40A modeller machine (Roland D.G.).

"Mechatronics" class provides a learning tool to develop a mechatronic system with PIC microprocessor, LED, sensor, and motor. Students can learn how to use mechatronics for interactive artistic expression. This means that this class is not targeted for developing a functional mechatronics component to complete a specific task.

"Robotics" class requires students to develop an actual robot that moves like an animal. Students must design the structure and appearance based on a motif animal, and must develop a robotic or mechatronics system to express the motif animal motion and behaviour. In such case, open loop or sequential control, not feedback control, is used to drive robot, because robot is not required to complete a specific task.

In summary, students in design education have some knowledge and skill for developing a robot[6-8], but they have not acquired the significant backbone enough to develop a functional element and feedback controller essential to make a robot complete specific task. Therefore, students require an appropriate guidance to develop an effective robot for Robot-Triathlon contest. On the other hand, design education students have enough skills to draw a good poster and design a robot appearance. So I always ask the participants to consider both robot function and aesthetic appeal.

Table 1. Comparison of Education between engineering and design

knowledge and skill	Eng.	Design	class (grade) in design education
Mechanical elements design	○	×	none
Mechanism design	○	×	none
Mechanical function Design	○	Δ	**"Robotics" (4th)**
Electronics	○	Δ	**"Mechatronics"(3rd)** and of "Engineering Foundation"(1st)
Digital Circuit	○	Δ	**"Mechatronics" (3rd)**
Appearance design	×	○	**"Robotics" (4th)**
Material fabrication	○	○	"Fabrication Practice"(1st and 2nd)
C language programming	○	×	none
Poster drawing	×	○	"CAD/CG Practice"(2nd)
CAD	○	○	"CAD/CG Practice"(2nd)
Rapid Prototyping	○	○	**"Prototype Simulation I"(3rd)**

4 ROBOT DESIGN

4.1 Shade

Shade, a design prize winner in 2010, is a kit based stylish car like robot (Figure 1). The roof can open to make it easy to set up and maintain the circuit board (Figure 2). Three blue LED lights are settled at the front on both sides. Controlled by another circuit board with a PIC microprocessor, they twinkle in sequence. Shade appearance was designed using SolidWorks 3D-CAD software (Figure 3). Using the SolidWorks Assembly, we can understand that the roof can open (Figure 4). The body is composed of chemical wood fabricated using a modeller machine. After polishing and applying a primer surfacer, Shade external was painted in black colour. Shade did not have any mechanism to pick up and release object. So this robot targeted to reach a goal line with line tracing and detecting object function based on the standard robot kit. In the time competition, Shade could trace black lines and go through the wandering forest but it did not move fast enough to reach the replacing object work area in time. So it was intended to retire.

Figure 1. Stylish car like robot Shade

Figure 2. Roof opened

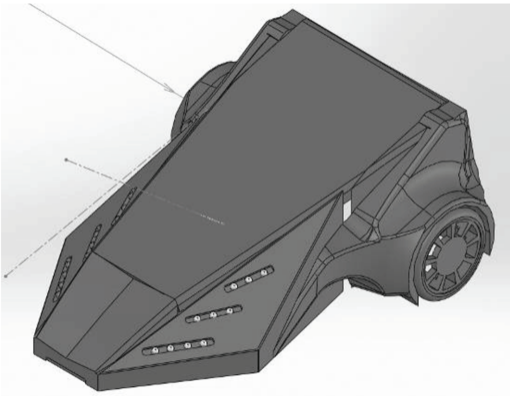

Figure 3. Shade SolidWorks 3D Model

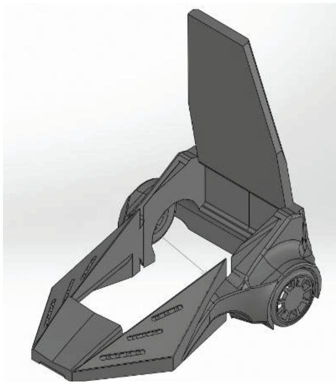

Figure 4. Shade model with roof opened

4.2 Riden

Riden is a trident motif mobile robot and it has the three pronged spear shape [9]. Figure 5 and 6 show the actual model and its 3D-CAD mode, respectively. Riden can pick up an object using the centre spear of trident in which two servo motor is embedded. This mechanism was assessed using a movement study model before design (Figure 7) and each part was evaluated by SolidWorks Assembly Analysis (Figure 8). Riden body was modelled by a fused deposition modelling machine FDM Vantage I (Stratasys) and the centre spear of trident was fabricated by a modeller machine MDX-40A.
Riden won a design prize in 2013 contest but it did not work in the time competition because of trouble with electronic circuit around motor driver.

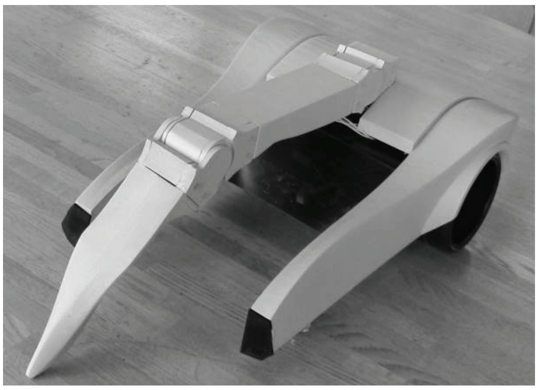

Figure 5. Actual Riden model

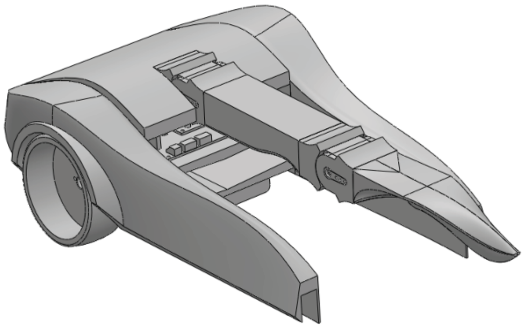

Figure 6. Riden 3D-CAD model

Figure 7. Center spear motion study

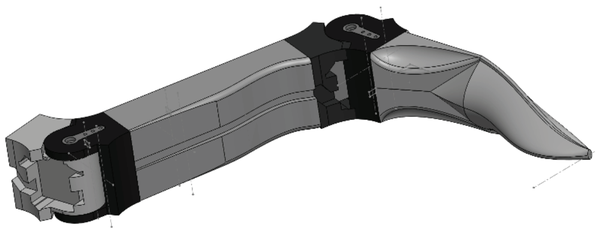

Figure 8. Assembly study of Center spear

4.3 Jurin

Figure 9 is a design prize winner robot in 2014 named Jurin came from wooden ring. Its appearance is composed of wood material fabricated by the modeller machine. Each part was designed using SolidWorks Software. Figure 10 and 11 show a front part and gear ring part, respectively. Jurin can scoop an object using a nose driven by a couple of gear ring in which a DC motor with gear box is embedded. Jurin has a crucial drawback in its weight because it is difficult to fabricate a wood material into a thin part. The actual front part obtained from Figure 10 was about 11 mm in thickness and the weight of 300 g, and total weight is about 1 kg. This means that Jurin cannot move fast and cannot turn in a small radius, therefore it is difficult to adjust its trajectory so as to find a black line. In the time competition, Jurin could not pass through the first crank line.

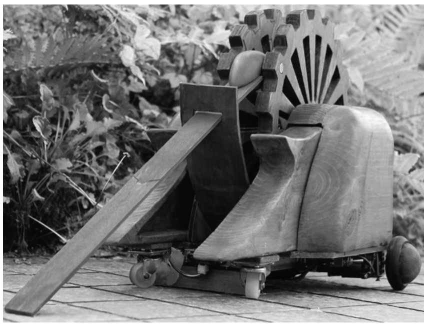

Figure 9. Wooden mobile robot Jurin

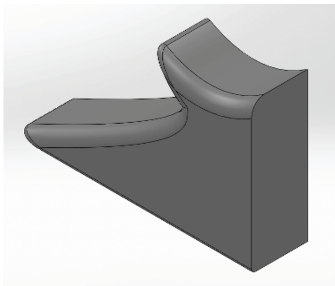

Figure 10. Front part

Figure 11. Gear ring

4.4 Discussion

All robots were modelled using the SolidWorks 3D-CAD software and fabricated using rapid prototyping, relevant to “Prototype Simulation 1”. Riden, developed its body using the FDM machine, was applied an advanced way based on “Prototype Simulation 1”, because the FDM machine can use the same data as the modeller machine MDX-40A. The FDM machine can model hollow objects which can put in sensor, circuit board gearbox, servomotors and wires. Students developed Riden considered how to put in these components in modelling using 3D-CAD, and they tested its design validity using SolidWorks assembly simulation tool. I think that this is a design educational effectiveness.

Shade added a LED lighting object which electronic components were obtained based on “Mechatronics” skill and knowledge. This means that the developers used mechatronics to enhance aesthetic appeal, students in engineering have never used.

The most notable characteristics of Jurin is its body material, whereas general robots were composed of metal and engineering plastic. Jurin was designed using SolidWorks and wood materials were fabricated by the modeller machine MDX-40A. This is a kind of “Prototype Simulation 1” process except wood material. Each wooden part was fabricated from both sides. After one side fabricated, it was upset so that its origin did not move. It is an application skill learned in “Prototype Simulation 1”.

However, no robots could get arrived at the goal line. This is caused by the design education curriculum characteristics that C language, control engineering, and mechanical design classes are not offered. Actually, only one robot could complete the course among all my robots during 2010 to 2016. In order to record good results in time trial, design education must cover C language and control engineering to develop an appropriate controller, and must include mechanical design to optimize robot weight and structure. Therefore, no robot achieved the replacing object work area though some robot had a function to pick up objects.

However, to add such engineering classes as control engineering, C language, and mechanical design to the design education is not much the times when we consider the advancement of technologies nowadays. I think it is necessary to give design education students an opportunity to cooperate with engineering education students, because inter-professional work by various field specialists is essential in actual society. This means that minute interchange among engineers who develop functions and designers who design its appearance are required to develop such new products as robots.
All products must give specific functions to consumers. And in case of robotic products, for example, housework robot or communication robot, designers must design their appearance with exerting their abilities maximally, because such robots will share living space with consumers, or will work as a partner of human. So robot design must be done by an appropriate way which is quite different from general commodities and consumer electronics.

5 CONCLUSION

My students joined in Robot-Triathlon contest and several robots they developed won the design prizes. Robots introduced in this study were modelled using the SolidWorks 3D-CAD software and fabricated using rapid prototyping, relevant to “Prototype Simulation 1” and several other relative classes are effective for robots to enhance aesthetic appeal. However, my students do not have enough knowledge about C language and control engineering to reach the time trial goal as well as mechanical design to suitable for whole Robot-Triathlon course including the replacing object work area.
At the next step, my students must make a team with students in engineering students in order to make this experience more worthy for students in design education. So I must plan a new cooperation design/engineering class to give design students a chance to cooperate with engineering students via participation in such the robot contest. In this class, students of both fields will discuss each other and they will think how to develop a robot which has functions to complete all tasks with keeping good appearance based on design concept. After several revisions, final model will be achieved. The effectiveness of cooperation will be evaluated by the contest results of both time trial and design prize.

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