Abstract

In designing and manufacturing such robotic and mechatronic systems, the engineers need a wide range of knowledge that includes electronics, mechanical engineering and information engineering. The purpose of this education is for students to give active learning for robotics and mechatronic techniques such as embedded controllers, motor driver circuits, sensors and to create structural drawings. To realize this goal, “an interest in creation” of student is regarded as an important educational method. In this paper, a systematic educational method for robotics and mechatronics education using “their interest” was introduced. The method is to hold robot competitions every year between 1st and 3rd year students as a regular part of the curriculum. To confirm the educational effect of this curriculum, the result of the Rescue Robot Contest that students participated were introduced. In addition, the educational curriculum was award as a good engineering education from Japanese Society for Engineering Education. As a result, it can be confirmed that the robot competition is a useful method to make students study more actively robotics and mechatronics technology by themselves.

Keywords: Systematic robotics education; Robot competition; Embedded controller
1. Introduction

To design and manufacture robotics and mechatronic devices that includes embedded controllers, engineers need to have a wide range of knowledge. However, it is difficult to learn it in a short period. Especially, in the four years educational curriculum of universities, there is not enough time to learn various area of engineering.

The purpose of this education in our university is to train students so as to master robotics and mechatronics techniques that includes techniques and knowledge about embedded controllers, motor drive circuits, sensors and to give the ability to create structural drawings for students. The final goal of the education is “Development of engineers who can create the robots (machines) by themselves”. In order to realize this goal, we regard that “an interest in creation” of student is an important educational method. It is well known that students who enter in the engineering course have much interest in creative work. In this paper, the educational method for robotics and mechatronics creation using “their interest” is proposed and tried. The method is to hold robot competitions every year between 1st and 3rd year students as a regular part of the curriculum as a systematic education.

2. Importance of robot competition in the engineering education

In order to make this education more effective, the educational method using robot competitions was used. Table 1 shows the time schedule and working processes of a typical robot competition. In the beginning of the competition, all members that includes senior and younger students have a meeting about the idea and functions of the robot. Next, the senior students make an assembly drawing of the robot. In the production process, the younger students make the mechanical parts. The senior students make the control circuit using an embedded controller, and wrote some programs for the embedded controller. All members assemble the robot. In the checking process, nobody succeed in making available robots without modifying and improving the robot. After running tests of the robot, the younger students make additional mechanical parts to modify the robot, the senior students re-design and improve the robots from both viewpoints of hardware and software. Finally, they enter the competition. The process of the robot competition includes "Plan", "Do", "Check" and “Action” processes. The whole process is similar to real creative works in companies. The checking process is a good opportunity to learn engineering knowledge and techniques from their errors and failures. In addition, both processes of the robot competition and company’s production have a time limit. One is the day fixed for the competition. The other is the appointed date of delivery. To meet the deadline, the leaders must make a plan for making and testing the robot. These experiences help them develop leadership. As a result of the robot competition, even if they fail, they have a good opportunity to get engineering knowledge and techniques. Their interest and the experience of their failures make the educational efficiency higher. In addition, the repeating experience of creative work such as robot competition helps to develop good mechatronics and robotics engineer. Therefore, a systematic educational program for robotics and mechatronics engineering using robot competition was proposed and carried out. The program includes three robot competitions. First-year competition is held for understanding the summary of the mechatronics and robotics system using an embedded controller. Second-year competition is for educating the technology about embedded controllers and mechatronics systems. Third-year competition is for education so as to plan and design the robot.
3. Mobile robot competition using vibration motor for freshmen

For an engineering education, the freshmen period when students are taking their first engineering lectures is very important. Therefore, the special curriculum was applied to the freshmen as soon as they enter our university. Fig.1(a) shows a sample of mobile robots that the 1st year students made. The robot consists of several vibration motors (4 or 6 motors), an embedded controller (micro-computer) and a motor driving circuit. The embedded controller can select to drive the motor according to a program, that is, the timing of each motor is controlled by the embedded controller based on a sequence control program that the students developed. The robot can move in any direction by changing the timing of the driving motors.

![Fig. 1. (a) tested mobile robot; making process of writing board (b) electric parts; (c) writing board; (d) setup for testing.](image)

Table 2 shows the schedule of this training class. In the first 3 weeks, the students make the embedded controller and the writing board that can have the control program installed through a serial communication port as shown in Fig.1(b), (c) and (d). From the 2nd to 8th weeks, the students design the control circuit. Figs. 2(a) and (b) show the electrical parts to make the driver circuit and a view of the students working. In this period, teachers only teach the operational principle and a few samples of the electric motor driving circuits. The students must consider how it can connect to the embedded controller by using their experience of making the writing board. From the 8th to 10th weeks, the students design the body of the robot by using computer aided design (CAD). They make the body of the mobile robot as a card model using cardboard based on the mechanical drawings that they designed. From the 10th to 12th weeks, the students design the control program for driving the vibration motors. It is difficult to control the mobile robot so as to make the robot move straight or rotate without changing the arrangement of the vibration motors. To control the motion of the robot, the students must investigate the mobile characteristics of the robot by changing the arrangement of motors and the control program through trial and error. Unfortunately, the students have not learned programming, a computer language and dynamics. “To win the competition”, they need to modify the sample control program written in C language, that is, they also need to study these subjects by themselves. In addition, some of them will study about the mechanism of various machines and physics such as inertia. They finished making their robots in 12 weeks (18 hours). Before the competition, the students adjust both the software and hardware of the robot at the same time. These students’ trials make them notice the importance of dealing with both elements of “Software” and “Hardware” as a creative work. In the last 3 weeks, the straight and rotating moving trials as shown in Figs.2 (c) and (d) are held as robot competitions. The result (record) of the student in the class is decided according to the ranking of these competitions. In these competitions, the students can know the ranking of their team in real time.

![Fig. 2. making process of controller (a) robot module parts; (b) design of circuit; robot competition (c) straight moving trial; (d) rotating trial](image)
4. Automatic Searching Robot Competition for 2nd Year Students

As a curriculum for the second year students, an automatic searching robot competition is held⁴⁻⁵. Fig. 3 (a) shows the automatic searching robot that the second year students made. The robot consists of two stepping motors, four infrared displacement sensors, photoelectric sensors, an embedded controller and a motor driving circuit. The embedded controller can decide the moving direction of the robot according to sensor values from the displacement sensors and the photoelectric sensors. The displacement sensor is used to detect obstacles, such as a wall. The photoelectric sensor is used to detect the target, that is, the high output infrared lamp. The main purpose of this education is to make the students learn the knowledge and techniques about electric circuits and embedded controllers such as a programming using C-language. Fig. 3 (b) shows the schematic diagram of the control system in the robot. The embedded controller detects the displacement between the robot and the obstacles through the analog to digital (A/D) converter in the embedded controller and the displacement sensors. It also detects the direction of the target from the robot through the A/D converter and the photoelectric sensors. The embedded controller selects to drive the stepping motors. To drive the robot using the stepping motors, the students must learn and use many functions of the embedded controller, such as a timer, I/O ports, A/D converter, serial communications and so on. The students must also make the body of the robot according to the assembly drawing made by CAD. They also make the electric control circuit of the robot that includes the serial communication port, the transistors and connector between the ports in the embedded controller and several sensors. The manufacturing process of the control circuit makes the students master the complex technical knowledge and techniques surely, so that the students can design and make the control system using the embedded controller by themselves. The students also deal with both the hardware such as the electric circuit, and the software such as C-language programming of the robot. In addition, in process of creation, students met many machine troubles. The student must find the cause of these problems. At first, it is necessary to distinguish whether the problem is related to hardware or software. The solution for the problem must be found by themselves. These experiences will help them make the various control systems or machines in the factory as a future work. As same as the curriculum for freshmen, the automatic searching trial for light goal using their robots as shown in Fig. 3(c) were held. The result of the student is also decided according to the ranking of the competition.

5. Remote-controlled robot competition for 3rd year students

As a curriculum for the third year students, a remote control robot competition is held⁶⁻⁷. The regulations of the robot competition is as follows; 1. The plane size of the robot must be within 400 x 400 mm. 2. The mass of the robot is less than 6.5 kg with batteries. 3. The total cost for making the robot is less than 50,000 Japanese yen (about 420 U.S. dollars). 4. The robot can be controlled remotely through wireless control device (Digi International Inc. XBee). In the competition, two types of competitions are held. One is a tug-of-war robot competition in which the powerful robot with low speed is one of the advantageous methods to win. The other is a ball toss robot competition that requires speedy robots with good maneuverability.
Fig. 4 (a) shows the competition field of the ball toss game. The robot must pick up seven golf balls set on cylindrical pins with various heights and get them into cups. This time trial competition is done within five minutes. So that only one robot from each team can enter both competitions, the students must consider the trade-off of the specifications of the robot in the period of planning and designing. From the educational point of view, in the curriculum, the teachers mainly aim to develop students’ ability to design and plan the robot. This training class is shared by the two curricula. One is a design competition for a mechanical design of the robot based on the strength and materials and a cost planning to make the robot. In the design competition, the achievement of each student is assessed by their plan with mechanical assembly drawing, parts drawings and a parts list. The other is the robot competition using the students’ developed robots. Fig. 4 (b) shows the view of the competition and the tested robot. The embedded controller in the robot was connected to the laptop computer through the wireless communication device (XBee). The operator gave the serial code to the embedded controller on the robot by using a typical game controller through a PC and wireless communication devices. The embedded controller selects to drive the various actuators based on the serial code. The various control devices used in the robot had to be included in the students’ advance plan in the design competition. It means that the students can make a plan for the complex driving system and design the robot by themselves. In addition, the students used the water jet cutting machine and the laser cutting machine as shown in Fig. 4 (c) for making parts of the robot to decrease the time for fabrication. Therefore, all robot were designed based on CAD. Whenever the students were faced with troubles, they always discussed about the problems each other. According to the result of meeting, their robots were redesigned and modified. The design of the controller on the robot was also repeating redesign and modification. These behaviors of finding problems and searching solutions for the problem give the opportunities of active learning for students. From the result of external evaluations about this curriculum, the senior engineer with experience evaluated that this curriculum is useful as a career education for engineers.

6. Educational Evaluation

In order to evaluate the development of our students for this education, in 2008, some students applied to the "Rescue Robot Contest" that is held in Kobe Japan. All members in this team were 4th year students. None of the members had applied for an official public robot competition previously. In short, this competition was a first-time trial for them. The regulations of the rescue robot contest is as follows: Fig. 5 (a) shows the image of the competition and the equipment used on the competition. The competition uses a one-sixth scale model of a city based on an imagined situation after a huge earthquake. The dummy robot in the field serves as a victim. The dummy robot can detect the applied acceleration and force as a damage by using an accelerometer and a pressure sensor mounted in the body. The robot also has a wireless communication device to send the information about the damage to the host computer. In the competition, the rescue robot is searching for the dummy robot, removing debris, rescuing the dummy robot and acting as an emergency transport. The operators can not look at the
They operate their robot through CCD cameras mounted on the robot. In the operation of the robot, the wireless LAN remote control unit as shown in Fig. 5 (a) is used. The control unit has 10 PWM output ports, 4 A/D input ports, 3 video input ports, wireless local area network ports and so on. In order to use these functions of the unit, the students need high level robotics and mechatronics techniques and wide areas of knowledge that are related to wireless communication equipment, control method, embedded control system and so on. In addition, in order to design the robot so as to make the best use of the control unit's functions, rich, practical creative skills and experience are also needed. It means that only the engineers who have abilities can win the competition.

![Image of rescue robot competition equipment](image)

**Fig. 5.** (a) image and equipment of the rescue robot competition; (b) best robot award in the contest from the Robotics Society of Japan.

As a result, our student team took second place in the contest and the "Best Robot Award in the Rescue Robot Contest" as shown in Fig. 5 (b) was awarded to our team from the Robotics Society of Japan, a great honor considering that it was our first attempt. This story is good evidence of our educational evaluation for our particular educational method. Fig. 6 (a) shows a history of the systematic robotics and mechatronics education in our department. The department was established in 2005. The curriculum with mobile robot competition using vibration motor for freshmen began from 2006. From 2007, the curriculum for 2nd and 3rd year student were started. These curriculums have been carried out continually. In 2009, the master program in graduate school also began.
According to increase the number of students who had experienced these systematic curriculum, the ratio of presented student in international conference increases. It means that the “motivation for challenging to new thing” increases. Now, more than 70 % of master course students had presentation in international conferences. Ratio of number of students’ presentations and number of students is over 120 %. In addition, in 2014, the educational curriculum was awarded as a good engineering education from Japanese Society for Engineering Education as shown in Fig. 6 (b). As a result, it can be confirmed that the systematic robotics and mechatronics creative curriculum using the robot competition is useful to make students study robotics and mechatronics technology and engineering by themselves and to increase the “motivation for challenging” for students.

7. Conclusions

The systematic robotics and mechatronics education using the robot competitions in Okayama University of Science was introduced. The contents and educational target for three curriculums were also introduced. As a result, we concluded that the educational environment that includes competitions with group, subjects to find the course of problems and its solution and systematic creative works is useful to develop engineers who has ability to design the robot or the machine by themselves. In addition, the systematic robotics and mechatronics creative curriculum using the robot competition is useful to make students study robotics and mechatronics technology and engineering by themselves and to increase the “motivation for challenging” for students.

References

1. Akagi, T. et.al. Mechatronics Education for Freshmen in University -Mobile Robot Competition Using Vibration Motor-, Proceedings of 2nd International Forum on System and Mechatronics, Tainan: 2007, pp.371-376.
2. Akagi, T. et.al. Robotics and Mechatronics Education for Freshmen through Robot Competition:—Mobile Robot Competition Using Vibration Motor—, Journal of the Robotics Society of Japan: 2013, Vol.31, No.2, pp. 118-123(in Japanese).
3. “Education for freshmen”: http://www.are.ous.ac.jp/are/seminar/index.htm (in Japanese).
4. Akagi, T. et.al. Mechatronics Education Using Robot Competition- Automatic Searching Robot Competition Using Micro-computer -, Proceedings of 2011 JSME Conference on Robotics and Mechatronics: 2011, 2A2-G01.pdf (in Japanese).
5. “Education for 2nd year students”: http://www.are.ous.ac.jp/are/infRobot/index.htm (in Japanese).
6. “Education for 3rd year students”: http://www.are.ous.ac.jp/are/cdms/index.htm (in Japanese).
7. Fujimoto, S. et.al. Training of Mechanical Engineers by Robot Competition: Robot Contest Using Wireless LAN Remote Control Unit(Education through Robot Contest) , Proceedings of 2011 JSME Conference on Robotics and Mechatronics: 2011, 2A2-G05.pdf (in Japanese).
8. Akagi, T. et.al. Mechatronics Education Using Robot Competition in Okayama University of Science, Journal of Engineering Education Research, Special Edition: 2010, Vol.2, No.13, pp.64-69.
9. Osuka, K. et.al. Special edition “Rescue Robot Contest”, Journal of Japan Society for Fuzzy Theory and Intelligent Informatics: 2006, Vol.18, No.1, pp.3-58(in Japanese).
10. "Rescue Robot Contest": http://rescue-robot-contest.org/ (in Japanese).
11. "The Legend of Team Momotaro": http://www.are.ous.ac.jp/are/rescue/index.html (in Japanese).