Creative Design of Robotics Education Using LEGO

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Abstract: To develop the ability of innovative engineering design of students in the faculty or graduate school of engineering, the practice education is as important as the lectures of knowledge teaching. In this paper, we introduce our innovative practice education of robotics, and a series works created by the students of Yamaguchi University using LEGO Mindstorms NXT. A set of LEGO Mindstorms NXT has parts of one body with CPU, 5 kinds of sensors, 2 servo motors and many bricks and pieces released by LEGO Company in 2006. To stimulate the activity of creative ideas of students, we usually request nothing about the shape or the aim of the works that every team must accomplish in 5 weeks. Technique supports which are methodologies of soft computing such as fuzzy inference and control, artificial neural networks, evolutionary computation methods, etc., and develop kits using C++ language. Students had their fun, and the abilities of programming development, innovative practice, and technical communication were raised in the creative practice of our robotics education.

Key-Words: *Innovative Practice of Engineering Education, Robot, LEGO Mindstorms NXT, C++ Language, oftcomputing, Fuzzy Inference, Artificial Neural Networks, Reinforcement Learning, Genetic Algorithm, webots*

1. Introduction

The education of the innovative engineering design is necessary in nowadays of modern age for students in colleges, universities and graduate schools. Engineers are expected not only skills or techniques on their major fields such as mechanics, electricity, electronics, information systems, and so on, but also abilities of innovation, creation, design, communication, management, cooperation, mentality, etc. For example, to promote a new project developing a system such as satellite or airplane, experts of different fields work together to provide high techniques and new ideas.

The education of computer science and robotics has been widely provided in the world [1]. Primary school students in Japan use the personal computer and the internet to investigate geography or social phenomena. High school students in USA improve their programming ability with the practice of robotics [2].

To develop the abilities of innovative engineering design of students, a new curriculum of undergraduate students in the Department of Information Science and Engineering (DISE) of Yamaguchi University (YU) has been provided since 2008. Based on the subjects of “Practice of Information Engineering I” which trains the application ability of basic robotics and computer hardware of students in grade 2, a subject named “Practice of Information Engineering II” which trains the application ability of software techniques such as C language and digital circuit of students in grade 3 is provided in the first term. For the grade 3 students, “Practice of Creative Manufacturing I” which mainly provides an application experience of image processing techniques, and “Practice of Creative Manufacturing II” which mainly trains the innovative design of robotics are constituted in the second term. Furthermore, subjects such as “Practice of Advanced Creative Manufacturing”, “Practice of Information Security”

for graduate students are provided to educate the higher abilities of information processing and creative manufacturing.

In this paper, we introduce creative designs of robots by undergraduate students attending "Practice of Creative Manufacturing II", and by graduate students with "Practice of Advanced Creative Manufacturing". Specially, their various designed products using LEGO blocks [3] and a computer part named LEGO Mindstorms NXT [4] [5] are presented.

2. LEGO Mindstorms NXT

LEGO Robot, a programmable robotics kit, is developed by the LEGO Group from 1998. The first original model was named RCX, and the next generation named NXT is developed in 2006. In Sep., 2013, a new model EV3 was released with a higher performance of computer.

In Figure 1, parts of LEGO Mindstorms NXT are shown in a circle, and a sample of LEGO robot named "inchworm robot" is shown in the right. The main component called NXT has 4 input ports and 3 output ports with a modified version of RJ12 cables. Its user interface is with 4 buttons for inputting instructions and a 100x60 pixel monochrome LCD display.

3. Works of Students

Subject "Practice of Creative Manufacturing II" is provided for the grade 3 students in DISE of YU. One team with 3 or 4 students learns to assemble a pre-designed robot "Golfer" shown in Figure 2 in 1.5 hour, and develop control programs with following 16.5 hours (5 weeks) using soft computing theories such as fuzzy inference, artificial neural networks (ANN), reinforcement learning (RL), genetic algorithms (GA), etc.

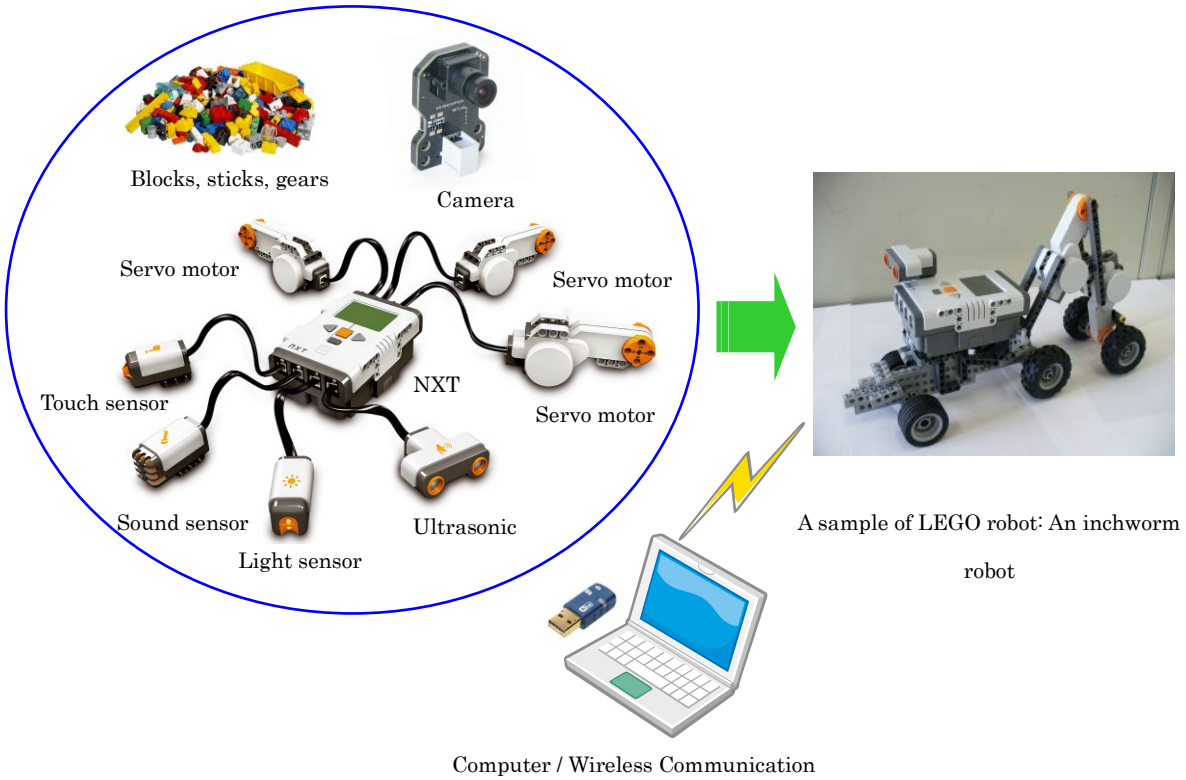


Figure 1 An intelligent robot composed by LEGO Mindstorm NXT

The oral presentation is executed at the last week with 5-10 minutes per team showing the succeeded or failed videos. The definition of success is to realize a goal ball search (red ball or blue ball) and approach to drop the ball from its stand (which is used as a landmark searched by ultrasonic sensor).

Figure 3-Figure 8 show various LEGO robots designed by the graduate students who graduated from different departments of YU: Dept. Mechanical Engineering, Dept. Electricity and Electronics Engineering, and DISE using 5 weeks (3 hours per week).

One team including different major students created rich innovative works such as Transporter (Figure 3), Crane Gamer (Figure 4), Ball Boy (Figure 5), Batter (Figure 6), Earthworm (Figure 7), and Throwing (Figure 8). Fuzzy control techniques were used in all of these systems, and applicable works suggest that subject “Advanced Practice of Creative Manufacturing” is effective to develop the ability of innovation, design and manufacturing of engineering of students. Additionally, LEGO mindstorms NXT was also used in the research of intelligent system design. To verify the effectiveness of novel systems using reinforcement learning evolutionary computation (genetic algorithms, etc.), artificial neural networks, etc..

Figure 2 Robot Golfer: A model for the creative design practice of undergraduate students (Grade 3). Robot searches the shelf by the ultrasonic sensor at first, then approaches to the goal, stops in the front of the red ball, rotates the arm to hit/drop the ball at last. Fuzzy inference was used to control the movement of the robot, and our source codes are opened in [6]. Download the video (919KB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/fuzzy.wmv

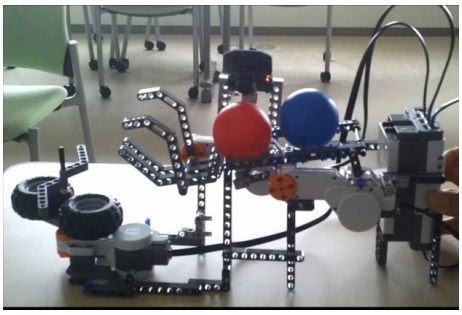


Figure 3 Robot Transporter: Robot distinguishes balls in different colors, and drops them in different places. Download the video (57.4MB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/transportor.wmv

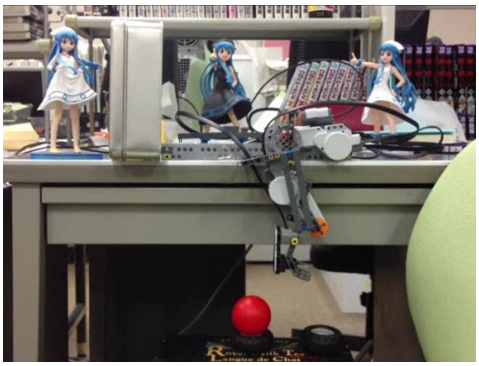


Figure 4 Robot Crane Gamer: Robot moves to find the red ball by the camera, and grasps the ball to drop it into a hole. Download the video (6.35MB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/crane.wmv

Figure 5 Robot Ball Boy: Robot searches the red ball by its camera, and approaches to the ball to pick it up by a hand. Download the video (26.1MB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/ballboy.wmv

bio-information processing system laboratory in YU developed LEGO robots such as Inchworm controlled by a reinforcement learning system (Figure 9), Beetle controlled an optimization system using genetic algorithm (GA) (Figure 10), Painter using artificial neural network (ANN) (Figure 11), Rubik's Cube Player with a reinforcement learning algorithm (Figure 12), and so on.

Not only for the education of undergraduate students, graduate students, the practical education of creative engineering design using LEGO was also tried by a project "Hirameki Tokimeki Science" for the visitors of primary school pupils and middle school students [8]. School boys and girls learned to create their own original robots using LEGO blocks and control them by developing the control programs using icon connection (graphical) software of LEGO EV3 [9]. Samples of the works under the supervising of graduate students are shown in Figure 13 and Figure 14. In the video of Figure 13, a robot judges the color of a ball in front of it and turns to throw the ball. The direction of throwing is designed as if the red ball comes then right, and left for the blue ball. In the case of Figure 14, a line tracing robot runs on the dark line avoiding the obstacle in front of it automatically.

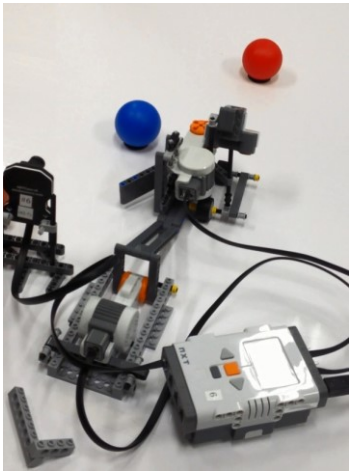


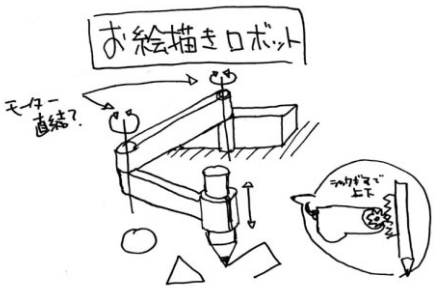
Figure 6 Robot Batter: Robot calculates the position of the red ball by the camera, and changes the angle of an arm which hits the blue ball to the red one. Download the video 21.7MB:
http://www.nn.csse.yamaguchi-u.ac.jp/video/batting.wmv

Figure 7 Robot Earthworm: A robot moves itself according to the expansions and contractions in different dimensions of the body. Download the video (6.1MB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/worm.wmv

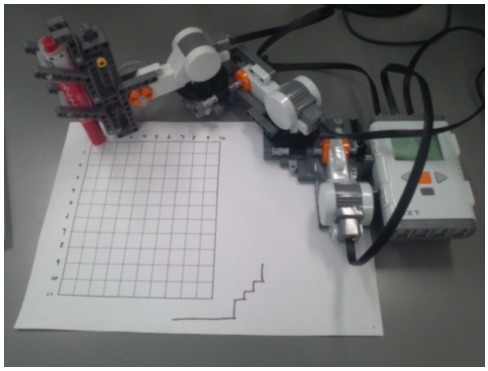
Figure 8 Robot Throwing: A robot throws a blue ball to attack a red ball in front of it by calculating the variable distance using images captured by a camera. Download the video (10.5MB):
http://www.nn.csse.yamaguchi-u.ac.jp/video/throw1.3gp

Figure 9 Robot Inchworm: Robot moves to a destination by the movement of expansion and contraction of the arm according to the learning result of reinforcement learning. Download the video (1.52MB): http://www.nn.csse.yamaguchi-u.ac.jp/video/LEGO2009inchworm.wmv

Figure 10 Robot Beetle: Robot goes up side avoiding to crash to the black lines in the center of the square according to the optimization result of genetic algorithm. Download the video (591KB): http://www.nn.csse.yamaguchi-u.ac.jp/video/beetle.wmv



(a) The design



(b) The robot

(c) A painting of robot

(d) A painting of robot

Figure 11 Robot Painter: Robot learns to draw a painting as same as a seen it saw according to a trained artificial neural network. Download the video (10MB): http://www.nn.csse.yamaguchi-u.ac.jp/video/lego.wmv

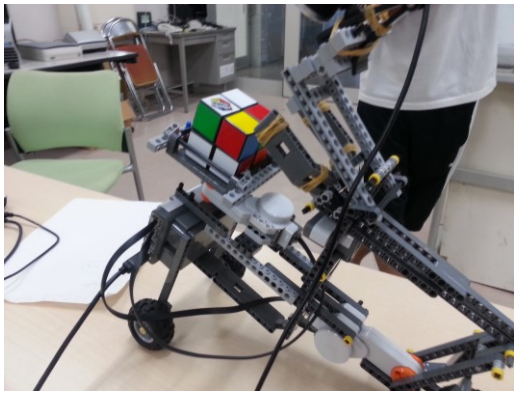


Figure 12 Robot Rubik's Cube Player: A robot to solve Rubik's cube game according to the reinforcement learning result. Download the video (184MB): http://www.nn.csse.yamaguchi-u.ac.jp/video/rubik2012.mp4

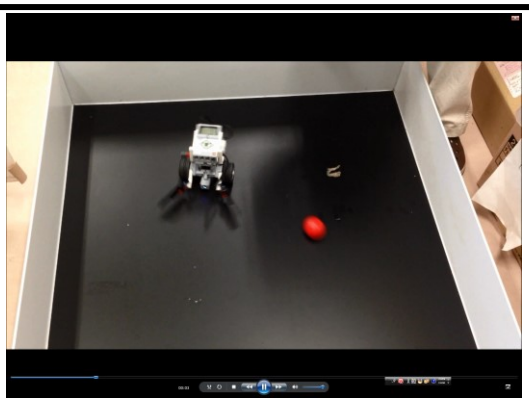


Figure 13 Ball Playing Robot: A robot can recognize the color of the ball in front of it and throw out it quickly with different direction according to the color of the ball. Download the video (15.3MB): http://www.nn.csse.yamaguchi-u.ac.jp/video/hirameki_geshi.wmv

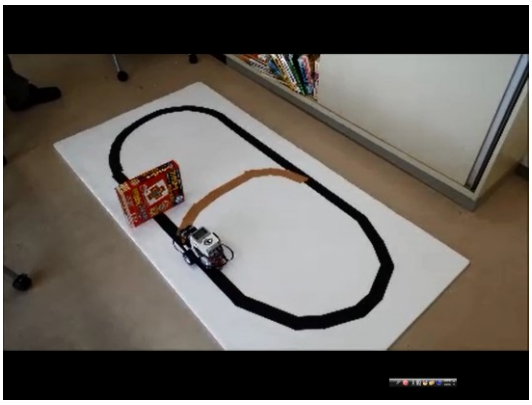


Figure 14 Line Tracer Robot: A robot runs on the black line avoiding the obstacle in front of it automatically. Download the video (2.04MB): http://www.nn.csse.yamaguchi-u.ac.jp/video/hirameki_gotoh.wmv

4. Conclusion

In this paper, the various robots created with LEGO Mindstorms NXT by students in YU were introduced. The effectiveness of education of innovative engineering design and manufacturing is remarkable. Students showed their interesting in the practice subjects. 431 parts of the LEGO give the availability to design a variety of robots according to ideas of designers.

We also use robot simulation software Webots [7] in the creative design of robotics education. Parameters and learning process can be acquired easier by the utility of the simulator. Moreover, the abilities of programming development and the intelligent system design of the students are more easily to be raised in a less learning period by using the simulation software.

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