A Teaching Reform of the Programming Course Based on Robot Competition for the Automation Major

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Abstract. Against the backdrop of new engineering education, the teaching of the automation major needs to be reformed based on the model of engineering education. As a practical course for the automation major, the programming course needs to incorporate more flexible and diverse projects into the classroom to fulfill the reform. The Robot Competition, an interesting, practical and innovative form of educational activity, can greatly improve students' engineering skills and creative thinking, increase their interest in learning, and enhance their academic performance. The practical training for the Robot Competition is carried out in a task-driven, group-cooperation and assessment-based manner. Students need to design the robots and code the programs themselves. The robots are optimized as the course proceeds, and a competition is held at the end of the course. The robot competition has achieved remarkable performance in improving the teaching effect, providing a demonstrative example for nationwide adoption and enjoying a broad prospect of broader application.

Keywords: robot competition; programming; automation major; new engineering.

1 Introduction

New engineering education, a newly proposed education theory in China, has strategic importance for enhancing the strength of industries and national competitiveness in the world. It is the mission of colleges and universities to promote the development of new engineering education, improve the cultivation of outstanding engineers, and speed up the revolution of the industry structure [1]. The success of the new engineering education will considerably increase the national hard power and the soft power.

China's initiative of new engineering education has now entered a new stage of implementation and quality improvement, with the proposal of "Tianjin University New Engineering Construction Program 2.0" in June 2020 that followed the start of "Tianjin University Program" in April 2019 [2].

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In the context of new engineering education, it is necessary to remove barriers between teaching and learning, promote the problem-oriented teaching model, and provide students with experiential learning, project-based learning and immersive learning experience.

Through new engineering education, students can combine theoretical knowledge with practical skills to solve engineering problems. Then, they can combine scientific research with product development to improve their skills in creative design and develop creative solutions. It also helps improve the students' capacities in teamwork, project management, and leadership.

The revolution of engineering education has led to substantial changes in the education of automation students. It is also urgent to reform the programming course, a practical course for the major of automation. In this paper, a new model of experimental teaching for the programming course is proposed as a tentative revolution and exploration to improve the effect of the programming course.

2 Overview of Programming Courses of The Automation Major

2.1 New engineering education in the automation major

Automation is a discipline that combines the knowledge and skills of machinery, electronics and computer science based on the theory of automatic control. It is a blend of control and management, strong electricity and weak electricity, and software and hardware [3]. Education of automation students should keep abreast of the development of science, technology, and the economy. In addition to fundamentals of mathematics, natural science and automation, students should also pay attention to professional skills, practical abilities, and communication and teamwork skills. In the context of new engineering education, it is necessary to equip engineering students with all-round skills in design, research, development, operation in automation and related fields.

However, the traditional educational model of the automation major overemphasizes content about traditional industries and cannot organically incorporate features of "intelligent manufacturing" (such as robotic technologies) into the framework of new engineering education, making it more difficult for automation students to keep up with the development of new technologies, new industries, and new economic trends.

Therefore, courses for automation students at universities should be reformed around the theme of new engineering education. Teaching methods and assessment methods should be reformed into a learner-centered model to meet the needs of new situations of economic development. Innovative practice platforms should be built to engage automation students in innovative practice activities, strengthen their innovative thinking, and enable them to adapt to the age of intelligent manufacturing.

2.2 Overview of the programming course

The programming course is a fundamental course for engineering students, especially for those majoring in automation. It is a core course in the "1+X" framework of University Computer Foundation education, as shown in Fig. 1.

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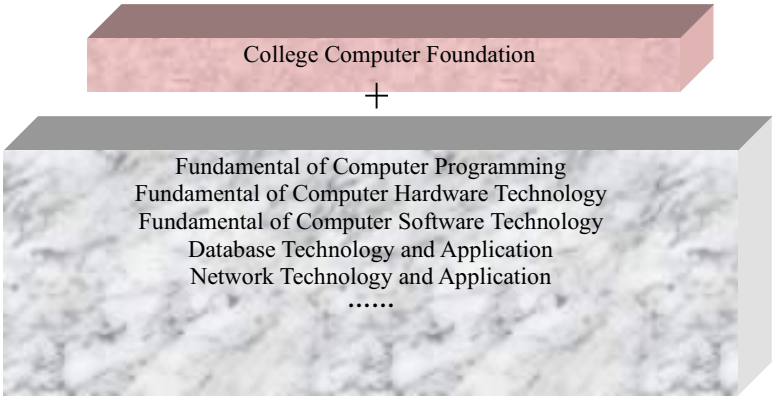

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Fig. 1. Core courses of the framework of "1+X" University Computer Foundation Education

The core courses of the framework of "1+X" University Computer Foundation education consist of one college computer foundation course and several required or optional courses. The programming course is a required course among them for the automation major. In the framework, College Computer Foundation is a prerequisite course, which lays a foundation for other professional courses on computer software, network and artificial intelligence, etc.

The programming course aims to familiarize students with basic concepts, methods and skills of programming, and equip them with skills to analyze, model, and solve engineering problems. The course intends to upgrade the students' capacity to solve engineering problems with computer skills.

The programming course is highly systematic. The topics involved in the course are highly correlated, and programming algorithms and programming data structures are strongly connected. It is also highly correlated to engineering practice as students can learn to design corresponding procedures and solutions to engineering problems. The course is highly practical. Students in this course need not only master programming languages, but also resolve real-world problems with programming.

2.3 Shortcomings of traditional experiments in the course

As programming languages are an important tool in many fields, experiments are essential in the programming course. At present, experiments for engineering majors are generally set up in software programming projects [4-8], including offline or online

programming, independent or cooperative programming, appointed or open programming, and many other forms of software programming.

However, as the new engineering education revolution moves forward, it is not advisable to apply the practical teaching form of traditional programming courses directly to the education of automation students.

First of all, software programming practice alone doesn't satisfy the need for "software-hardware-combination" for the education of automation students. As a basic course that equips students with the tool of programming, the programming course is introduced into the classroom of many majors. However, the practice of programming is usually designed as software development projects, in other words, all programs are designed and run on the computer. One advantage of this kind of practice is that the required hardware environment is simple and the organization of the class is convenient. It is also convenient for the students to take part in practice. However, the education of automation students calls for a "software-hardware combination", so it is necessary to design programming practices for specific electromechanical systems. Practice projects of traditional programming courses cannot achieve the connection of the "programming tool" with "engineering practice". Thus, it is urgent to introduce a new practice teaching form so that students can apply programming skills to the development of electromechanical systems, and fill the gap between different engineering courses.

Second, students are generally averse to the learning mode in which they have to face the computer screen and codes. Though traditional tasks of programming are interesting, such as developing gobang games, programming practice remains a problem. The students use a lot of software in daily life, so when faced with simple programming, they show little interest in learning and can have a very limited sense of achievement when finishing the programming task. Therefore, it is necessary to introduce new forms of practice and new practical platforms to the students to stimulate students' interest. At the same time, the practice results are presented in a physical and vivid way to enhance the sense of achievement in programming practice.

In summary, amid the new engineering education revolution, it is necessary to introduce flexible and diverse projects of practice to meet the increasingly higher standards for training automation students.

3 Practice Teaching Based on Robot Competition

To adapt to the new situation, universities have increased the proportion of practical teaching in the programming education of automation students [9].

Therefore, during the implementation of the programming course, we break away from the traditional teaching mode, and introduce the robot competition into the programming course for automation students as an important part of practical teaching. The robot is designed and assembled by the students themselves, and then the software is programmed and the robot competition is organized. The results of the competition are considered as part of the course examination.

3.1 Overview of the practice environments

The practice session of the programming course is carried out in the College Robotics Innovation Practice Base [10]. A modular combined robotics platform, which is a combination of hardware and software, is used in the practice. Students are required to work in groups, design and assemble their robots and program the system software. Then, the robot competition is held at the end of the course.

The hardware platform is the Lego Mind-storms robot platform, which is a collection of programmable hosts, motors, sensors, gears, axles, beams, pins and other related parts. The platform can be programmed and assembled into a variety of functional robots to achieve various functions, as shown in Fig. 2.

(figure from the UserManual of Lego Mind-storms.
https://education.lego.com/en-us/downloads/mindstorms-ev3/software)

Fig. 2. Some key robot components used in the practice (NXT controller, servo motors, photo-electric sensors, sonars, voice sensors, touch sensors)

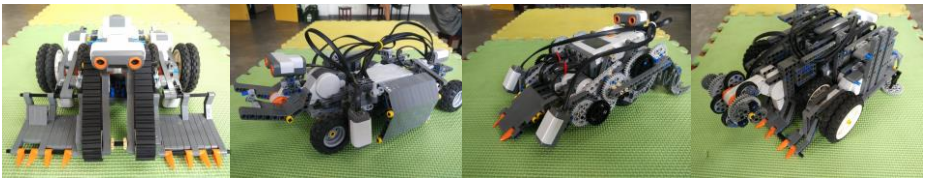

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Fig. 3. Examples of robots designed and assembled by the students

The robot controller in the competition is the 2nd generation NXT controller, with Bricxcc (Bricx Command Center) as the programming environment, as shown in Fig. 4.

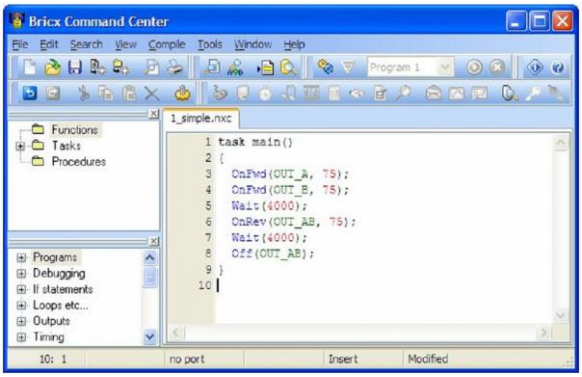

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Fig. 4. The Bricxcc programming environment used in the robotics competition

Students need to use the practice platform to design and assemble their robots. Then, they implement the program on Bricxcc, and use the assembled robots to compete against each other on the designated competition field. The size of the competition field is 160cm*160cm, with a 35*35cm square hole in the middle, as shown in Fig. 5.

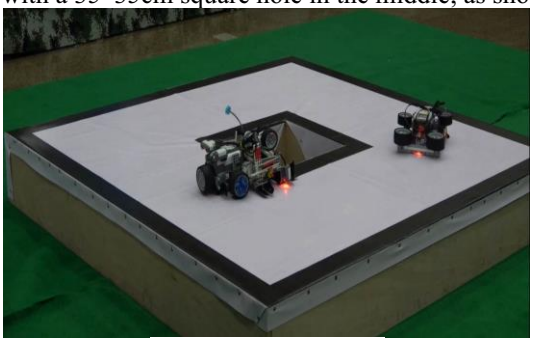

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Fig. 5. The competition field used in the robot competition

The robots are installed with sensors to detect the surroundings, and the robot controller processes the sensor information and controls the robot motors to perform moves as designed in the program. During the competition, two robots move autonomously on the competition field to push the opponent robot. One robot wins when the other falls off the field or loses the ability to move.

3.2 Organization of practice teaching

The practice teaching based on the robot competition can motivate students to deepen their understanding of theories in competitions, and group work can reduce the challenge of the task and strengthen their team spirit. The learning effect is examined by the competition.

The tasks of the practice are assigned at the beginning of the course, and students need to work in groups of three. Then, students design and assemble their own robots and program the software during the course. Students continue to optimize the robots' functions as the course progresses, and finally compete against each other at the end of the course.

The robot competition is held between different classes of the programming course. The teams will first compete with each other in a round-robin manner within the same class, and then compete in the elimination stage between different classes. The quarterfinals, semifinals and finals will be held for the 16 teams from different classes.

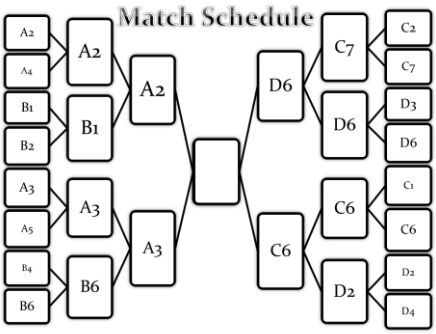

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Fig. 6. Demonstration of the elimination schedule of the robot competition

In the competition, the robots must be assembled based on the hardware provided by the specified platform and be programmed using the specified programming language (C language). Each game opens with two competing robots placed back-to-back in the field and starting simultaneously for competition. The robots run fully autonomously during the match, and students are allowed to remotely control or interfere with the movement. Each game lasts two minutes, and one competitor loses if his/her robot leaves the playing field. If there is no winner in the game, the teams will be weighed and the lighter team wins.

All robots are designed and assembled outside of the class, and the competition is held outside of class as well, since the robot competition is considered as an extracurricular activity. The final ranking of the robot competition is introduced in the course assessment, and scores are given according to the ranking. The competition score accounts for 20% of the total score of the course.

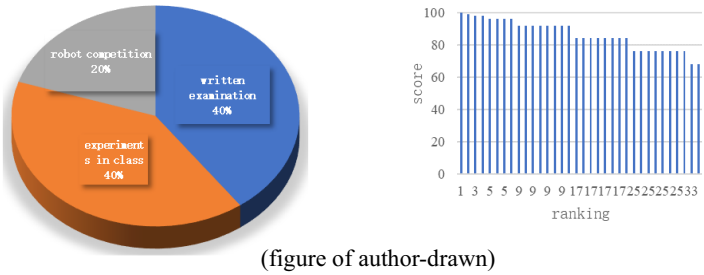

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Fig. 7. Demonstration of the structured scoring of the course and the scores corresponding to the rank of competition

4 Results and Benefits of the Practical Teaching

Since the introduction of the robot competition as a form of extracurricular practice teaching, it has won praise from the students. Students have not only gained knowledge, but also improved their engineering skills and innovative thinking.

Moreover, it allows the students to master more knowledge and skills that are not taught in class through practice.

As the robot competition is fun, practical and innovative, it is now influential beyond the course and has been covered by many media both inside and outside of the college. The Robotics Culture Festival held by the college each year has introduced the robot competition as a regular activity of the festival. Now robot competition is gaining increasing popularity among students. The robot competition has also been covered in the live broadcast "All the Children in the Nation", which is jointly launched by the Network Department of the PLA News Communication Center, the Business Development Center of the China Care for the Next Generation Working Committee, the China Children's News Publishing Corporation, and Tencent WeTV. The robot competition has also been spread across the borders in the global community [11].

During the 2020 National Conference of Deans of Automation Teaching in Colleges, the robot competition was displayed as a result of the education reform of the automation major, which was highly evaluated by the participating experts and became a new highlight of the college.

(figures captured from TV shows and news. (a) https://www.nudt.edu.cn; (b-c) PLA News; (d)Tencent WeTV)

Fig. 8. The robot competition covered by the media. (a) robot competition in the programming course; (b) robot competition covered by the military media; (c) robot competition in the Robotics Culture Festival; (d) robot competition in live broadcast of "All the Children in the Nation".

5 Conclusions

Against the backdrop of new engineering education, the programming course of the automation major needs to undergo innovative practical reform according to the characteristics of the automation major and students' education requirements. Due to the interesting, practical, and innovative characteristics of the robot competition, the robot competition is introduced as a course practice in the teaching process of automation students. The robot competition practice can greatly enhance students' practical

skills and innovative thinking, and it can also stimulate students' learning interest and improve the learning effect. The practice teaching reform of the robot competition has achieved remarkable results and gradually gained popularity across the nation, with great prospects of wider adoption.

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