Exploring the teaching model of an industrial robotics course based on integrated theory-virtual-practice

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Abstract. In order to meet the demand for high-end industrial robotics talents in China, according to the current industrial robotics courses offered by applied undergraduate colleges and universities, there are problems in the teaching process such as incomplete content and inability to combine theoretical knowledge with practical operation due to the limited teaching time. This paper pro- poses the idea of using the teaching materials as the basis, combining RobotStudio simulation soft- ware-ABB industrial robots for the integrated theory-virtual-practice, highlighting the cultivation of practical ability and innovation ability, improving the teaching quality of industrial robotics courses and students' comprehensive ability, and providing teaching reference for cultivating industrial robotics application-oriented talents.

Keywords: Applied undergraduate; Industrial robotics; RobotStudio; Integrated teaching of integrated theory-virtual-practice; Teaching mode

1 Introduction

With the advent of Industry 4.0 era, the traditional manufacturing industry has turned to digitalization, intelligence and network development[1-2]. In this context, in 2015, the state released "Made in China 2025" manufacturing power strategy[3], with industrial robots as the representative of intelligent manufacturing and high-end equipment into the key technology of intelligent manufacturing shall be strongly developed [4-5]. This brings opportunities and challenges to our applied undergraduate education, which requires our applied undergraduate education to clarify the orientation of industrial robotics curriculum, curriculum construction, how to cultivate applied, innovative and high quality high-end technical talents, solve the contradiction between the rapid growth of industrial robotics industry and the serious shortage of professional talents, cultivate more number of industrial robotics application talents, and truly realize the arrival of high-end talents immediate use [6].

The course on industrial robotics, as a basic course for mechanical majors, includes the development of industrial robots, structural components, kinematics and dynamics, sensors, control systems, offline programming and simulation, and operation and

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programming[7]. This has led to a number of courses being taught at different stages of the curriculum, making it impossible for students to correlate the content and learn what is taught in the industrial robotics course, and pre- venting theory from being linked to practice and students from being trained in hands-on skills.

2 Characteristics of traditional teaching

As a core foundation course for mechanical engineering in applied undergraduate institutions, industrial robotics is characterised by a wide range of basic knowledge, cross-discipline, practicality and difficulty in learning[8]. this course provides a deeper understanding of industrial robotics based on a comprehensive knowledge of mechanical design, mechanical manufacturing processes, mechanical drawing, nonlinear control theory and programming technology[9]. The teaching arrangement of industrial robotics courses is not standardized enough. For the elective courses of mechanical design, manufacturing and automation and mechanical and electronic engineering, the teaching content of industrial robotics is reasonably limited by class time, and students can only gain surface knowledge, but cannot learn and master the knowledge of industrial robotics in depth, nor can they improve their personal cognition to a certain extent. There is also no focus on the individual skills of industrial robotics students, which results in a lack of hierarchy in the teaching of the subject[10].

3 Objectives of the industrial robotics curriculum reform

3.1 Student Competency Development objectives

Firstly, students need to acquire basic knowledge and skills in industrial robotics, such as robot construction, control systems, programming and operation. Through practical exercises, students can improve their technical skills and master robot operation and maintenance skills. Secondly, students need to be creative and able to identify problems and propose solutions in practice. They need to learn to think and analyse, identify problems in robot operation and come up with innovative solutions, thus improving their creative skills. In addition, in robotics operations, students need to collaborate with other students to complete tasks. Through teamwork, students can learn to collaborate and support each other, improving their teamwork skills. Finally, students need to learn to communicate effectively with other students and their teachers in order to better complete their tasks. Through communication, students can learn to express their ideas and opinions and improve their communication skills。

3.2 Objectives for the development of students' core competencies

One of the goals of the reform of the industrial robotics curriculum is to develop students' ability to apply their core skills in an integrated manner. This means that students need to master several skills and be able to apply them in practical situations.

Firstly, students need to master the basic principles and structure of robots, including knowledge of robot kinematics, dynamics and control systems. Secondly, students need to understand robot programming methods and languages, and be able to write programmes to achieve autonomous control and movement of the robot. Integrated application skills are one of the key qualities of industrial robotics talent and an important direction for the future development of industrial robotics. By reforming the curriculum and developing students' core skills in integrated application, it will help to improve the innovation capacity and competitiveness of industrial robotics in China.

4 Industrial robotics curriculum reform measures

Firstly, in the teaching process, teachers should introduce other relevant theoretical content based on the theoretical foundations of the Industrial Robotics course, combining these different pedagogical knowledge in a complementary way and enabling students to work on detailed design and accessory operations, which can effectively guide students to deepen their knowledge of the composition and specific performance of each component of an industrial robot. Secondly, project-based training in the Industrial Robotics Training Centre. In order to further equip students with the practical operation of industrial robots, the school offers "Offline Programming of Industrial Robots", in which students can program and simulate industrial robotics training projects in the laboratory using Robot Studio software for industrial robotics training centre practical training projects. Again, the ABB Training Centre is relied upon to carry out the "physical operation" aspect of the course, with the teacher playing a role in demonstrating, guiding and instructing. The teacher uses theoretical and practical skills to analyse and interpret tasks, decompose them into knowledge points and operational specifications, guide students in the actual operation of the robotics equipment to complete the task, remind them to observe experimental phenomena, look for operational rules, and help summarise knowledge points.

5 Design of teaching methods for the integrated theory-virtual-practice

Due to the complexity and abstract nature of industrial robotics courses, students often find it difficult to understand and grasp the knowledge. In order to solve this problem, this paper adopts the integrated theory-virtual-practice integrated teaching method in the industrial robotics course to provide students with a better teaching experience and learning effect. The integrated theory-virtual-practice integrated teaching method refers to the combination of theoretical knowledge, virtual simulation and practical operation to form a complete teaching system.

First, the teacher should explain the basic concepts, principles and applications of industrial robotics. Through the lectures, students can understand the theoretical knowledge of industrial robots in terms of classification, structural composition, offline programming and operation and programming. Secondly, on the basis of the theoretical knowledge, the teacher in charge of the course guides students to carry out virtual simulations of industrial robots. Through the virtual simulation, students can understand the laws of motion, workflow and operation of industrial robots. The virtual simulation also helps students to understand the role of the control system and sensors in industrial robots. Finally, the instructor uses the ABB operating platform to guide students through practical operations. Students are guided through the operation of the robot, programming and debugging. Through practical work, students gain an in-depth understanding of how industrial robots work and how to operate them, and acquire relevant skills and experience. The integrated teaching method of theory and simulation can help students to learn industrial robotics better. Through the combination of theoretical knowledge, virtual simulation and practical operation, students can gain a comprehensive understanding of the knowledge and skills related to industrial robotics and improve their learning effectiveness and practical skills.

6 Example of the application of the teaching method of integration of theory and reality

Take Chapter 6 of the textbook on the operation and programming of typical industrial robots as an example. The chapter on the operation and programming of industrial robots introduces the basic operation, programming and application examples of the ABB robots, using the ABB robots as an example. Firstly, the basic components of the demonstrator（As shown in Figure 1）, the function of each button and the interface of the demonstrator display are explained according to the textbook, so that students can understand the operation of the demonstrator and the function of the buttons; secondly, the format and examples of simple commands in the demonstrator programming, such as MoveJ, MoveL, MoveC and other motion commands, are explained, so that students can under- stand their application in robot programming; finally, a simple practical example is used to summa rise the content of this chapter. Finally, the chapter is summarised with a simple practical example to provide students with a foundation for virtual simulation and practical exercises.

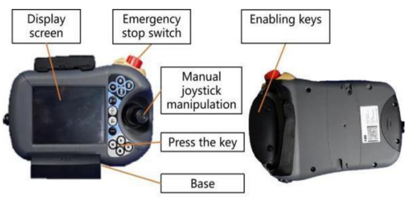

Fig. 1. Demonstration

After learning the theoretical knowledge, students learn to open the trainer through the Robot- Studio software, open the RobotStudio software to create a new ABB robotics integration platform, call up the virtual trainer, and view the robot motion status through the operation of the trainer keys, so that students can further understand the virtual trainer key func- tions and trainer programming instructions, and lay a good foundation for practical operation.

In the RobotStudio software, learn the MoveAbsJ, MoveJ and MoveC instructions through the program editor in the demonstrator, and practice format editing and adjustment of programming instructions with a circle trajectory project, and demonstrate programming and debugging of circle trajectories in the virtual demonstrator. Through the circle trajectory demonstration programming, students learn in-depth industrial robot operation and programming.

Through theoretical lectures and virtual demonstrations of the demonstrator and programming, students gained a deep knowledge of the robot demonstrator and programming language. In order to combine theory, virtual simulation and practice, groups of students were taken to the ABB robotics lab to further understand the functions of the demonstrator by students operating the ABB robotics integrated platform demonstrator buttons and editing the demonstrator operating interface。

In order to deepen the students' learning of the programming of the demonstration, or take the example of the circular trajectory, the virtual simulation program of the circular trajectory by the RobotStudio software, the circular trajectory is edited by the ABB Robotics demonstrator, and the students firstly program and debug by themselves according to the knowledge they have learnt, as shown in Figure 2 Circular trajectory debugging. In the process of operation, the students point out the problems that they do not encounter in the theoretical knowledge and virtual simulation, for example, the switching of axes, the switching of axes and linear coordinates, and how to make the end perform the vertical walking circle trajectory.

Fig. 2. Commissioning of circular trajectories

Through a combination of theoretical lectures, virtual simulations and practical exercises on the operation and programming of typical industrial robots in Chapter 6, students are motivated to learn, helping them to deepen their theoretical knowledge and improve their creative and hands- on abilities.

7 Conclusion

This paper proposes an integrated teaching method that combines theoretical knowledge, virtual simulation software and robotics equipment operation, so that theoretical knowledge, virtual soft- ware simulation and actual equipment operation can be integrated and mutually promoted. The design of the integrated teaching method breaks the segmented teaching mode of theory, virtual and practical operation, especially for majors who only offer the course of industrial robotics, from theoretical knowledge lecture, virtual simulation to hands-on training, which truly achieves the teaching concept of combining theory and practice, improves teaching quality, and enhances students' enthusiasm for learning and skills operation.

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