Construction and Practice of Modular Progressive Project Experiments of Robot Kinematics

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Abstract. Robot kinematics is the basis of robot integrated application. This paper analyzes the shortcomings of the robot teaching process in local applied colleges and universities. Focus on industrial robots that are widely used in the industrial field and have a large market scale, and build a modular robot kinematics experiment system guided by capacity requirements, including three modules: industrial robot motion simulation project, industrial robot programming project, and industrial robot visual guidance flexible grasping project, which can meet the needs of different knowledge levels and different teaching links. It can be used for the mixed teaching, in-class experiment and comprehensive experiment of related courses, and provide some ideas for the exploration of the teaching mode of the core course of robot engineering in applied universities.

Keywords: Application-oriented university, Robot kinematics, Experimental system, project experiment, Mixed teaching

1 Introduction

At present, robots are greatly changing the way of human production and life. With the continuous integration of information technology and industrialization, the intelligent industry represented by robot technology is booming and has become an important symbol of scientific and technological innovation in the new era [1]. Robots have the advantages of high flexibility and low labor cost, and are widely used in various industries [2-3]. Robot kinematics analysis and trajectory control is one of the key problems to be solved in robot integration applications.

The existing robot trajectory control methods mainly include teaching programming [4] and offline programming [5]. Teaching programming sets the robot's job track points online through the teaching device, which limits the efficiency and quality of complex tasks [6]. Offline programming can be divided into computer-aided design and vision-based programming methods, which have obvious advantages in complex operating environments [7]. In particular, the robot trajectory control based on machine vision integrates artificial intelligence technology and robotics technology. The introduction of machine vision technology into the robot motion control ex-

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perimental system is of great significance to robot education, teaching and scientific research.

In recent years, there is a large shortage of robot engineering and technical talents, and the training of robot engineering professionals has been highly valued [8]. Since robot technology involves multidisciplinary knowledge such as machinery, electronics, control, computer and artificial intelligence, and the professional positioning of different types of colleges and universities is different, it is difficult to form a unified standard for the training curriculum system of robot engineering professionals in different types of colleges and universities, and there are few course resources that can be directly used for reference [9]. For application-oriented undergraduate colleges, the work that robot engineering students are mainly engaged in after graduation includes robot ontology design, drive control, integrated application, intelligent production line design, etc. In the process of talent training, practical ability and innovation ability should be strengthened [10-11]. Robot technology is characterized by a close combination of theory and practice, and the research and development of robot technology and personnel training cannot be separated from robot experiment teaching [12]. Therefore, the robot experiment teaching platform plays an important role in personnel training and scientific research [13].

Robot kinematics is the core knowledge point of Robotics, which is the core course of robot engineering. It is also the foundation and core ability of robot drive control and integrated application. The existing robot kinematics teaching process mainly teaches D-H parameter method, homogeneous coordinate transformation and forward and inverse kinematics analysis, which is highly theoretical and complex and abstract. Simple theoretical explanation without the assistance of experimental teaching will inevitably make it difficult for students to understand and combine theory with practice. In addition, according to the survey and literature analysis, the existing experimental teaching on robot kinematics is mostly based on virtual software simulation or a single practical operation, and there are few kinematics experiments for industrial robots, especially the mixed teaching of professional core courses, in-class experiments and professional comprehensive experiments lack systematic experimental schemes. Experimental teaching is prone to problems such as single content, lack of material resources, and unsystematic knowledge content, which is difficult to meet the needs of different knowledge levels and different teaching links [14-15]. Therefore, we should focus on industrial robots which are widely used in the industrial field and have a large market scale, build a modular robot kinematics experiment system, and flexibly support the mixed teaching, in-class experiments and professional comprehensive experiments of related courses. Among the core knowledge of robotics engineering, robot kinematics is the foundation of robot drive control and integration applications. At present, there are few kinematic experiments for industrial robots, and there is a lack of complete experimental system. Therefore, the development of robot kinematics experiment resources for practical application scenarios is of great significance to the talent training, curriculum resource construction and teaching reform of robot engineering major.

2 Construction of Robot Kinematics Experiment System

According to the needs of mixed teaching, in-class experiments and professional comprehensive experiments of related courses of Robotics, a modular and progressive robot kinematics experiment system is built around the core knowledge points of robot kinematics based on the idea of "basic training → intensive training → comprehensive training", as shown in Figure 1.

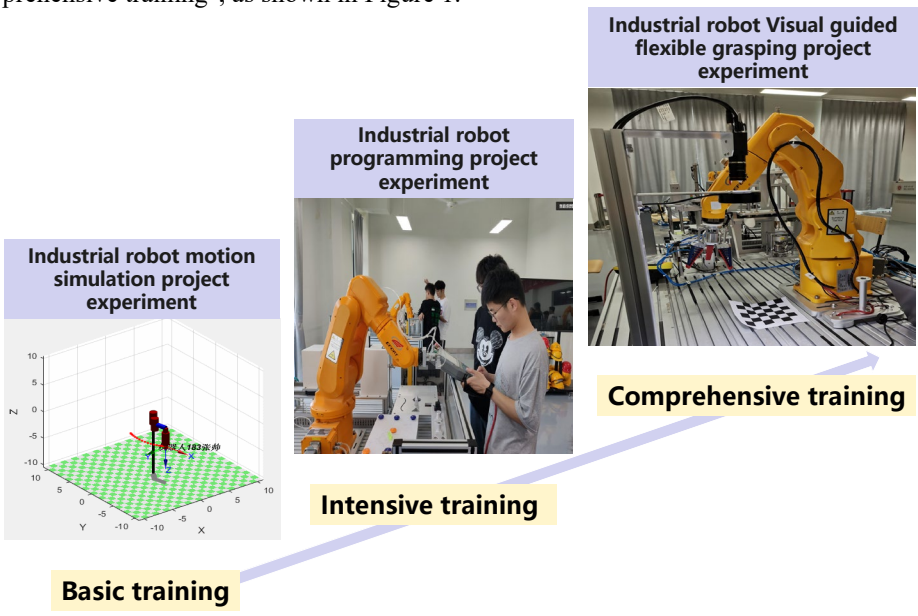

Fig. 1. Modular progressive robot kinematics experiment system

The construction of modular progressive robot kinematics experiment system mainly includes three modules: industrial robot motion simulation project, industrial robot programming project experiment and industrial robot visual guidance flexible grasping project experiment. Among them, the industrial robot motion simulation project is "basic training", the industrial robot programming project experiment is "intensive training", and the industrial robot visual guidance flexible grasping project experiment is "comprehensive training". The experimental content has the characteristics of combining virtuality and reality, which can meet the needs of different knowledge levels and different teaching links, and can be flexibly selected according to the actual teaching needs.

3 Robot Kinematics Experiment Project Design

3.1 Industrial Robot Motion Simulation Project Experiment

The experimental purpose of this module is to enable students to master the basic principles and methods of robot kinematics analysis, carry out forward and inverse kinematics simulation analysis and virtual verification of robots based on Robotics Toolbox, and strengthen the understanding of relevant knowledge points in classroom teaching.

The specific experiments included: Using Robotics Toolbox, DH parameters of the robot were determined according to the given actual robot structural parameters, and the simulation model of the robot was established; Based on the robot simulation model, the end pose and motion trajectory of the robot are analyzed, and the kinematics model of the robot is verified. In the course of classroom teaching, students can understand the ideas and processes of verifying robot kinematics modeling through mixed teaching or comprehensive homework.

3.2 Industrial Robot Programming Project Experiment

The experimental purpose of this module is to enable students to master the robot operation norms and teaching programming methods, and master the experimental verification methods of robot kinematics in combination with typical application scenarios such as trajectory walking and palletizing, so as to strengthen the ability of robot motion analysis and trajectory planning.

Specific experiment contents include: Through the form of in-class experiment, based on the experimental platform as shown in Figure 1, carry out the motion trajectory planning and verification of industrial robots based on teaching programming. The robot is controlled to move to the target position, and the attitude Angle and coordinate value corresponding to the target position are obtained by the teaching device. The correctness of the kinematic equation is verified by comparing the theoretical coordinate value of the robot end position with the actual coordinate value obtained from the kinematic equation.

3.3 Industrial Robot Visual Guidance Flexible Grasping Project Experiment

The experimental purpose of this module is to enable students to understand the principle of motion control of visually guided industrial robots. Through typical robot grasping application scenarios, with visual coordinate transformation motion analysis as the core, students can master the kinematic basis of robot integrated application and the multidisciplinary integration knowledge of machine vision and electromechanical control.

Specific experiment contents include: Through the form of professional comprehensive experiment, based on the experimental platform as shown in Figure 1, comprehensive experiment of industrial robot flexible grasping operation with visual guidance for specific application is carried out. Students are required to be familiar

with the basic principle of camera calibration technology and the derivation process of coordinate conversion, establish the conversion relationship between the end coordinate system of the robot and the camera coordinate system, and convert the coordinate value obtained by the camera into the coordinate value under the robot coordinate system, so as to realize the visually guided robot flexible grasping operation.

4 Practical Application and Promotion Value

The robot kinematics experiment system constructed in this paper is a summary of practice in the actual teaching process, and has been used and verified in the teaching process of robot engineering and related majors in our school. Through the form of mixed teaching, in-class experiment and comprehensive experiment, it can solve the problems that the content of robot kinematics is highly theoretical, the process is complex and relatively abstract, so that students can understand the ideas and processes of robot kinematics analysis, strengthen their intuitive understanding of robot motion analysis, visualize the abstract and boring kinematics analysis, and guide their active exploration. Develop the ability to analyze and solve problems. Through hybrid teaching and experimental teaching associated with practical application scenarios, students can understand the practical application value of kinematic analysis, master robot operation norms and teaching programming methods, and strengthen the ability of robot motion analysis and trajectory planning combined with typical application schemes such as trajectory walking and palletizing. Through typical robot grasping and other application scenarios, with visual coordinate transformation motion analysis as the core, master the kinematics foundation of robot integrated application and the multidisciplinary integration knowledge of machine vision and mechanical and electrical control, and achieve good teaching results.

5 Conclusion

Aiming at the shortcomings of the existing robot kinematics teaching process, this paper constructs a modular robot kinematics experiment system, which can meet the needs of different knowledge levels and different teaching links, and can be used for mixed teaching of professional core courses, in-class experiments and professional comprehensive experiments, and can be flexibly selected according to actual teaching needs. It has certain scientific and application value. Through hybrid teaching and experimental teaching, students can understand the practical application value of robot kinematics analysis, master the kinematic basis of robot integrated application and multidisciplinary fusion knowledge, and especially provide certain ideas for the reform of the teaching mode of robot engineering talents training in application-oriented undergraduate colleges.

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