Education and Social Work
ISSN Print: 3079-515X
ISSN Online: 3079-5168
https://doi.org/10.63313/ESW.9022

Research on the Application of Twin Technology in the Teaching of Industrial Robot Technology Practice Course

Qinghui Zhou[1]*. Hao Jiang[1] and Zhi Lei[2]
[1]Institute of intelligent manufacturing, Wenzhou Polytechnic, Wenzhou 325035 China
[2]Zhejiang Mingrui Intelligent Equipment Technology Co., Ltd 325035 China
*Email: 445782257@qq.com

How to cite this paper: Zhou, Q. H., Jiang, H., & Lei, Z. (2025). Research on the Application of Twin Technology in the Teaching of Industrial Robot Technology Practice Course. Education and Social Work, 1(2), 185–194. ISSN Print: 3079-515X; ISSN Online: 3079-5168.
https://doi.org/10.63313/ESW.9022
Published: 2025-04-22

Abstract

This paper Against the background of digital transformation in education, emerging technologies are gradually driving profound changes in the field of education. As one of the key technologies, twin technology demonstrates unique application value in the teaching of industrial robot technology practice courses. By constructing virtual teaching environments and simulating real work sce-narios, twin technology provides students with richer and more convenient practical operation opportunities, significantly improving the quality and effi-ciency of teaching and enhancing students' practical operation abilities. In terms of teaching applications, twin technology can achieve functions such as simulating virtual practical operation scenarios, implementing remote practical teaching, and providing teaching assistance and evaluation. The application re-sults are quite remarkable. Its significance to teaching is not only reflected in breaking through the limitations of traditional teaching in terms of time and space constraints and equipment dependence, but also in promoting the inno-vation of teaching models, laying a solid foundation for cultivating professionals who meet the needs of the intelligent manufacturing era.

Keywords

Twinning technology; Industrial robots; Practical course teaching; Virtual simulation; Teaching evaluation

1. Introduction

1.1. Background in Educational Science Planning Field

With the rapid development of information technology, the digital transformation of education has become a major trend in the global education field. Against this background, the digital transformation of higher education in China has also made remarkable progress. From infrastructure construction to the development of teaching resources, from the innovation of teaching models to the optimization of educational management, digital technologies are being integrated into the higher education system in an all-round way. Emerging technologies such as big data, artificial intelligence, and virtual reality are providing a strong impetus for educational transformation. They not only change the way knowledge is disseminated but also reshape the teaching and learning environment, promoting the development of education in a more personalized, intelligent, and efficient direction. For example, big data analysis can accurately assess students' learning situations, providing a basis for personalized teaching; artificial intelligence can achieve functions such as intelligent tutoring and automatic grading, improving teaching efficiency; virtual reality technology can create an immersive learning environment, enhancing students' learning experience. [1][2]

1.2. propose for research

In the wave of digital transformation in education, twin technology has occupied a key position due to its unique advantages. By constructing virtual models that interact with physical objects in real time, twin technology can achieve deep integration and analysis of data. The application of twin technology in the teaching of industrial robot technology practice courses is expected to break through the limitations of traditional teaching and improve the quality and effectiveness of teaching. Currently, the teaching of industrial robot technology practice courses faces many challenges such as limited equipment resources, high risks of practical operations, and monotonous teaching scenarios. Twin technology can provide new ideas and methods for solving these problems. Therefore, an in-depth study of the application of twin technology in the teaching of industrial robot technology practice courses has important practical significance. [3][4]

2. Significance of the Study

2.1. Enhancing Teaching Effectiveness

Twin technology brings about remarkable changes to the teaching of industrial robot technology practice courses by constructing a virtual teaching environment, effectively breaking through many limitations of traditional teaching and thereby improving teaching quality and efficiency. In traditional teaching, restricted by factors such as the number of physical equipment, space of the venue, and teaching time, it is difficult for students to fully carry out practical operations, and it is hard to effectively integrate theoretical knowledge with practical applications. Twin technology uses digital modeling methods to accurately replicate actual industrial robots in a virtual environment, creating highly realistic teaching scenarios [2]. Students can conduct operational exercises anytime, anywhere in the virtual environment, free from the constraints of time and space, which greatly increases practical opportunities. Meanwhile, the virtual teaching environment can simulate various complex working conditions and fault scenarios, enabling students to engage in exploratory learning in a safe environment, deepen their understanding and mastery of knowledge, and thus enhance the teaching effectiveness [4].

2.2. Cultivating Students' Practical Abilities

Twin technology can simulate real-world work scenarios, providing students in industrial robot technology practical courses with more abundant and realistic practical opportunities, thereby enhancing their practical operational skills. Real-world work scenarios are often complex and dynamic, involving multiple aspects such as the installation, debugging, programming, and maintenance of industrial robots. By constructing virtual scenarios with twin technology, these actual work processes can be highly replicated. Students can repeatedly practice the operational skills of industrial robots in a virtual environment, familiarizing themselves with the operational procedures and standards under different tasks [3]. For example, in a virtual environment simulated by twin technology for industrial robot palletizing operations, students can program and control the robot to perform tasks such as picking up, transporting, and stacking goods, thereby accumulating practical experience. This simulated practical approach enables students to acquire relatively proficient operational skills before entering their actual work positions, better preparing them to meet the practical needs of future work [5].

3. Twin Technology Theoretical Explanation

3.1. Concept of Twin Technology

Twin technology, or digital twin technology, is a method that fully leverages physical models, sensor updates, and operational history data to integrate multidisciplinary, multiphysical, multiscale, and multiprobability simulation processes. It creates a virtual mapping in the digital space to reflect the entire lifecycle of corresponding physical equipment [6][7]. At its core, twin technology involves constructing a virtual digital twin that is closely linked to the physical entity, enabling comprehensive, real-time monitoring, analysis, and control of the physical entity. In simpler terms, it creates a "clone" of physical-world entities in the digital world, where this "clone" can reflect the state and behavior of the entity in real time.

3.2. Twin Technology Principles

The realization of twin technology is based on key aspects such as data interaction and model construction [5][7]. In terms of data interaction, various sensors are used to collect real-time operational data from physical entities, such as position, speed, and temperature, and transmit these data to the digital twin model. At the same time, the digital twin model sends control instructions to the physical entity based on the analysis results, achieving bidirectional data interaction between the two. In model construction, the physical entity's shape model is first created using geometric modeling techniques, followed by the establishment of its physical behavior model based on knowledge from physics, mechanics, and other fields. Machine learning algorithms are also integrated to build intelligent analytical models, thereby forming a complete digital twin model to simulate the behavior and performance of the physical entity under various conditions.

3.3. Twin Technology Features

Twin technology possesses notable features such as real-time and visualization, which offer potential advantages for educational applications [6]. Real-time capabilities enable the digital twin to reflect the state changes of the physical entity in real time. In the teaching process, students can observe and understand the dynamic changes of the physical entity more intuitively.

To enhance the timeliness and authenticity of learning, real-time observation of industrial robot operation parameters and motion trajectories is crucial. Visualization presents complex data and models in intuitive graphical and image forms, facilitating students' understanding of abstract concepts and principles. For example, students can clearly see the internal mechanical structure movement and data flow transmission of industrial robots through the visualization interface, which helps improve teaching effectiveness and student engagement.

4. Industrial Robot Technology Practical Course Teaching Status

4.1. Issues with Traditional Teaching Methods

Traditional teaching methods present numerous challenges in industrial robot technology practical courses. Firstly, There are significant time and space limitations. Practical teaching usually requires students to go to designated training site training venues at specific times, making it difficult for students to learn flexibly according to their schedules. Additionally, the training venues have limited space, which cannot accommodate a large number of students conducting practical operations simultaneously [1]. Secondly, there is a strong dependency on equipment. Industrial robot equipment is expensive, and schools find it difficult to equip sufficient quantities of various models, resulting in limited practical opportunities for students and hindering their compreh ensive mastery of operating skills for different types of industrial robots [2]. Moreover, there is a shortage of teaching resources, including textbooks, case studies, and specialized instructors, which makes it difficult to keep the teaching content up-to-date with industry developments and meet students' diverse learning needs, thereby affecting the improvement of teaching quality.

4.2. Existing Educational Needs

There is a pressing need for innovative teaching methods and improvements in the practical teaching quality in current industrial robot technology courses. On one hand, with the rapid development of industrial robot technology, the industry's demands for professional skills and practical abilities of talents are constantly increasing. Traditional teaching methods are no longer sufficient to meet the needs of cultivating high-quality professionals, and innovative teaching methods are urgently required [3]. On the other hand, enhancing the practical teaching quality is crucial for improving students' employment competitiveness. By introducing advanced teaching methods, such as twin technology, to construct virtual practical environments, students can be provided with more and more realistic practical opportunities. This helps students better understand and master industrial robot technology, thereby improving the practical teaching quality and fostering applied talents that meet industry needs [4].

5. The Application of Twin Technology in Industrial Robotics Practical Courses

5.1. Simulation of Virtual Practical Operation Scenarios

Using twin technology to build virtual practical operation scenarios for industrial robots involves first creating digital twins. For example, with SimPro software, which supports the import of various 3D models, one can establish 3D geometric models based on the actual dimensions of real-world objects using professional modeling software such as SolidWorks, Nx, or ProE, and then import them [3]. Alternatively, the software’s own simple geometric modeling functions can be used to create 3D models. Additionally, behavior settings and construction are applied to the geometric objects, endowing them with electrical control and motion characteristics consistent with real industrial robots, thus achieving data interaction between physical and digital models [3]. This way, highly realistic virtual practical operation scenarios are created, allowing students to simulate operations such as palletizing with industrial robots, thereby familiarizing themselves with the actual operational procedures and key points in advance [5].

5.2. Implementation of Remote Practical Teaching

With the support of twin technology, remote practical teaching can be realized. By establishing virtual models of the robots and their working environments, a mapping from physical entities to digital twin models is achieved [8]. Teachers can utilize network platforms to share these virtual models with students, facilitating remote learning and practice. Sharing relevant teaching resources with students, students can access virtual practical scenarios from anywhere by logging into their terminal devices. For example, in a practical teaching platform based on digital twin technology for modular production systems, students can remotely participate in virtual modeling and virtual-physical integration of the MPS digital twin, overcoming geographical limitations and addressing practical teaching challenges caused by uneven distribution of equipment [9].

5.3. Teaching Support and Assessment

In terms of developing teaching support tools, twin technology can integrate rich educational resources such as operation demonstration videos and theoretical explanations, incorporating them into virtual scenarios in digital form. Students can access and utilize these resources at any time during their operations. In building the teaching assessment system, real-time data collection and analysis of students' virtual practical operations, including operational accuracy and completion time, are conducted to construct a comprehensive and objective teaching assessment system. For example, based on the performance data of students in a virtual industrial robot operation scenario, the level of mastery of operational skills can be evaluated, providing substantial evidence for teachers to adjust their teaching strategies [2][4].

5.4. Case Study Analysis

Taking a university's industrial robot technology practical course as an example, after introducing twin technology, A set of training software including a virtual practical operation scenario was developed. Students learn industrial robot programming and operation by conducting simulated training through this software. The practice shows that students have a deeper understanding of industrial robot systems, and their programming and operational skills have significantly improved. Additionally, since the virtual scenarios can simulate various complex working conditions, students' ability to handle actual problems has also been enhanced. Furthermore, through remote practical teaching, the teaching coverage has been expanded, benefiting more students and effectively improving teaching outcomes and quality [3][4].

6. Challenges and Solutions for the Application of Twin Technology in Industrial Robotics Practical Courses

6.1. Technical Implementation Difficulties

Twin technology faces numerous technical challenges when applied to practical courses in industrial robotics. On one hand, achieving precise synchronization between the industrial robot twin model and the physical entity requires the establishment of complex kinematic models and vibration mechanism mapping models. For instance, a kinematic model based on an improved Denavit-Hartenberg (DH) method must be developed, and the twin model must be driven by actual joint angles to achieve synchronized motion with the physical entity. However, this process involves extensive complex calculations and precise data matching. On the other hand, constructing a virtual scenario and integrating real operational data impose high demands on data processing and interaction technologies, necessitating real-time and accurate data transmission and processing to achieve virtual visualization simulation and strategy optimization.

6.2. Cost Implications

The application of twin technology involves significant costs. On the hardware side, high-performance computers and sensors are required to support the operation of the twin system and data collection, posing a challenge for the school's hardware infrastructure investment. Software costs are also substantial, as developing or purchasing specialized twin system software requires a large amount of funding. Additionally, the cost of personnel training is crucial, as teachers and students need to master the skills for applying twin technology. This training process involves expenses for instructors, textbooks, and training facilities.

6.3. Solution Strategies

To address the technical implementation challenges, schools can collaborate with research institutions and enterprises to jointly develop and research twin technology, leveraging professional expertise Strength conquers the modeling and data interaction challenges. Regarding cost input issues, the school can reasonably plan its budget, making phased investments in hardware and software, prioritizing core teaching needs. At the same time, it can apply for government and corporate funding to reduce its own cost pressure. In personnel training, internal training can be conducted, selecting key teachers to learn first, then gradually promoting it to other faculty and students to reduce training costs.

7. The Development Trend of Twin Technology in Industrial Robotics Practical Courses

7.1. Integration with Emerging Technologies

The integration of twin technology with emerging technologies such as artificial intelligence and big data is expected to give rise to new teaching models. In terms of integration with artificial intelligence, intelligent algorithms can perform in-depth analysis of the large amounts of data in twin models, achieving intelligent optimization and fault prediction for industrial robot operations [10]. For example, by monitoring and analyzing the operational data of industrial robots in real-time, an artificial intelligence system can predict potential faults in the robots and provide students with corresponding maintenance suggestions and operational guidance in advance. Big data technology can assist twin technology in collecting, storing, and analyzing massive amounts of industrial robot operational data, thereby building more precise twin models and providing students with more realistic teaching scenarios [11]. This integration can make teaching more targeted and forward-looking, enhancing students' ability to handle complex industrial robot systems.

7.2. Teaching Application Expansion

Twin technology has extensive potential for application in the teaching of industrial robot technology practical courses. On one hand, it can further extend to the teaching of the initial stages of industrial robot design and research and development, allowing students to fully participate in the design and development process of industrial robots in a virtual environment, thereby deepening their understanding of the entire lifecycle of industrial robots [2]. On the other hand, in terms of practical teaching evaluation, twin technology can achieve comprehensive and precise assessment of students' operational processes, not only focusing on the results but also analyzing every detail of the process, providing more targeted feedback and guidance to students [4]. Additionally, twin technology can be explored for application in innovation and entrepreneurship education related to industrial robot technology, stimulating students' innovative thinking and entrepreneurial enthusiasm.

8. Conclusions

8.1. Summary of the Study

This research focuses on the application of twin technology in the practical courses of industrial robot technology. As the digital transformation in education becomes a major trend, emerging technologies are driving educational change. Twin technology, with its unique advantages, demonstrates significant potential in the practical courses of industrial robot technology.

On a theoretical level, the concepts, principles, and characteristics of twin technology were thoroughly elaborated, clarifying its core essence of achieving virtual and real-world mapping through data interaction and model construction, as well as the positive impact of its real-time nature and visualization on teaching applications.

Given the current state of practical courses in industrial robot technology, traditional teaching methods face limitations in time and space, reliance on equipment, and insufficient teaching resources. There is a pressing need to innovate teaching methods and improve the quality of practical teaching. The application of twin technology effectively addresses these challenges by constructing virtual practical operation scenarios, allowing students to simulate Real-world operations, transcending time, space, and device limitations; achieving remote practical teaching to further expand the scope of teaching coverage; in terms of teaching support and assessment, it aids in the development of teaching support tools and the improvement of the teaching evaluation system. Through case studies, the significant achievements of twin technology in enhancing teaching quality and fostering students' practical skills have been verified. At the same time, the research also ana The lyzes the technical implementation challenges and cost is put into issues faced by twin technology applications and proposes. corresponding solution strategies. [2][3]

8.2. Research Prospects

Although this study has achieved certain results in the application of twin technology in industrial robotics practical courses, there is still vast room for research. In the future, as technology rapidly advances, twin technology is expected to deeply integrate with emerging technologies such as artificial intelligence and big data. For example, artificial intelligence can be utilized to provide intelligent guidance and adaptive assessment for industrial robot operations, while big data analysis can be employed to optimize the design of teaching scenarios and resource allocation, thereby creating more intelligent and personalized teaching models.

In terms of expanding applications in teaching, twin technology can further be applied to the course design and experimental development of industrial robot technology practical courses, not limited to practical operation teaching. At the same time, it is worth exploring how to apply twin technology to different levels and majors of industrial robot-related teaching to meet diverse teaching needs. Additionally, continuous attention should be given to cost optimization and technological innovation in the application of twin technology, lowering the application threshold, and promoting its use in a broader range of educational fields. This will provide stronger support for cultivating high-quality industrial robot talent. [2][10]

Acknowledgements

This paper was supported by Zhejiang Provincial Education Science Planning 2023 Annual general planning project "Teaching Practice Exploration of Deepening School-Enterprise Cooperative Education Based on Digital Twin Technology -- Taking Industrial Robot Integrated Application Technology Course as an Example" (Project No. : 2023SCG215), Zhejiang Province University Student Science and Technology Innovation Activity Plan (New Talent Plan) " Research on Robot Course Teaching Assisted by Digital Twin Technology "(Project No. :2023R452012).

References

[1] Xiangling Zhang; Qi Yuming; Sanpeng Deng; Qiang Xue; Renyuan Zhang. Key Technologies and Digital Twin Platform Application of a Multi-functional System for Industrial Robots [J]. Manufacturing Technology, 2024, (6): 11-15.

[2] Zhiyuan Gao; Jiaxi Zhao; Fumei Yan; Yaogui Li. Research on Simulation Teaching of Digital Twin Industrial Robots Based on Practical Training Cours-es—A Case Study of the Course "Offline Programming and Simulation of Indus-trial Robots" [J]. High-tech China, 2023, (20): 152-154.

[3] Chen Liang. Application Research of Digital Twin Technology in Vocational College Industrial Robot Practical Training Teaching [J]. Electronic Testing, 2022, (3): 138-139.

[4] Ouyang Qunxin. Practice of Digital Twin Virtual Simulation in Industrial Ro-bot Application Technology Courses [J]. Technology Wind, 2024, (10): 38-40.

[5] Chen Yujiao; Zeng Shi Yu; He Hongjie; Chen Fan. Research and Implementa-tion of Digital Twin System for Industrial Robot Stacking [J]. Computer Integrat-ed Manufacturing Systems, 2023, 29 (6): 1930-1940.

[6] Zhang Jian. Research on Industrial Robot Motion Simulation System Based on Digital Twin Technology [J]. Digital Communication World, 2024, (1): 10-12.

[7] Wang Zhenwei; Zhang Zhenshan. Research on Modeling Methods for Indus-trial Robot Twin Mapping Models [J]. Software Engineering, 2023, 26(6): 40-45.

[8] Chen Chengjun; Ding Xutong; Pan Yong; Zhang Hao; Hong Jun. An Online Teaching System for Remote Operated Robots Based on Digital Twin [J]. Com-puter Integrated Manufacturing Systems, 2023, 29(3): 951-963.

[9] Sun Shuwén; Ding Jiawang; Dong Mingjie; Huang Chao. Design and Imple-mentation of a Modular Production System Practical Teaching Platform Based on Digital Twin[J]. Experimental Technology and Management, 2024, 41(3): 244-250.

[10] Liang Chao; Tang Jing; Wang Ji; Zhou Jian; Wang Yuanhang. Re-search and Application of Digital Twin Model for Industrial Robot Health Man-agement[J]. Reliability and Environmental Testing of Electronic Products, 2022, 40(S02): 5-10.

[11] Ni Jinxin; Sun Wenlei; Liu Guoliang; Bao Shenghui; Zhang Kezhan. Research on Robot Motion Simulation and Virtual-Physical State Synchronization Mapping Driven by Digital Twin[J]. Modern Manufacturing Engineering, 2024, (5): 48-55.