Development and Teaching Innovation of Digital Twin Technology Course for Computer Science Majors

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Abstract: *With the continuous deepening of the application of digital twin technology in various industries, especially in the fields of intelligent manufacturing, smart cities, and the Internet of Things, digital twin technology has raised new demands for the teaching of computer science majors. In order to cultivate students' interdisciplinary knowledge, engineering practice abilities, and innovative capacities, this research discusses the development and teaching innovation of digital twin technology courses for computer science majors. The article first outlines the basic concepts, development history, and application needs of digital twin technology in computer science, followed by a discussion of the objectives and framework design for course development. It proposes a teaching method centered on project-driven learning, case analysis, and virtual simulation. Finally, the article establishes a diversified evaluation system and points out feedback and optimization paths for teaching innovation. Through this course design, the aim is to enhance students' theoretical literacy and practical abilities to meet the demands of digital transformation and cultivate high-quality technical professionals in the computer science field.*

Keywords: *Digital Twin Technology, Computer Science, Course Development, Teaching Innovation, Evaluation System*

Introduction

With the continuous advancement of digital transformation, digital twin technology, as a revolutionary emerging technology, is widely applied in various fields such as intelligent manufacturing, smart cities, the Internet of Things, and healthcare. Digital twin technology not only provides a virtual replica of the physical world but also enables the management and optimization of the entire lifecycle of physical entities. However, the rapid development of digital twin technology presents significant challenges for the education system of computer science, particularly in terms of curriculum design, teaching methods, and technical practice. Therefore, how to effectively integrate digital twin technology into the curriculum of computer science majors, cultivate students' interdisciplinary knowledge, data analysis capabilities, and system design skills, has become an important issue in the current reform of computer science education. This paper aims to provide theoretical support and practical guidance for the innovation of teaching models in computer science majors by constructing the goals, framework, and teaching innovation methods of digital twin technology courses, further promoting the popularization and application of digital twin technology in education.

1. Overview of Digital Twin Technology and Demand Analysis for Computer Science Majors

1.1 Development and Basic Concepts of Digital Twin Technology

As an emerging technological tool, digital twin technology initially originated in the aerospace field. With advancements in the Internet of Things (IoT), big data, cloud computing, and artificial intelligence, it has gradually expanded into multiple industries, including manufacturing, smart cities, and healthcare. The basic concept of digital twin technology is based on the mapping relationship between the physical and virtual worlds. By accurately modeling physical entities and their operational processes, it creates a dynamic, real-time updating virtual replica. This virtual replica is not just a static representation of the physical entity but can reflect changes in the entity's state in real time, enabling simulation, prediction, analysis, optimization, and decision support.

Digital twin technology allows for the monitoring, prediction, and optimization of the entire lifecycle of physical entities through virtual models, offering smarter and more precise management tools. In the field of computer science and technology, the core value of digital twin lies in modeling and simulating complex systems, processing and analyzing large-scale data, as well as integrating and coordinating various technical platforms. As digital transformation deepens, the application prospects of digital twin technology are expanding, bringing new demands for the education and teaching methods of computer science majors[1].

1.2 Key Components and Working Principle of Digital Twin Technology

The core components of a digital twin system typically include physical entities, virtual models, data transmission and analysis platforms, and feedback mechanisms. Physical entities form the foundation of digital twin technology, referring to objects such as industrial equipment, transportation systems, and building facilities that need to be modeled and monitored. Virtual models are the digital representations of physical entities, achieved through sensors, data acquisition systems, and high-precision modeling algorithms to precisely reproduce the spatial and temporal dimensions of physical entities. The data transmission and analysis platform handles the transmission, storage, and processing of real-time data, typically supported by big data technology, cloud computing platforms, and artificial intelligence algorithms for data analysis and optimization.

The working principle of digital twin technology is based on the real-time synchronization and analysis of data streams. During operation, physical entities are continuously monitored by sensors to capture their states, behaviors, and environmental changes. These data are transmitted in real time to the virtual model for processing and updating. The virtual model then uses data analysis, machine learning, and optimization algorithms to perform in-depth analysis, generate predictions about future states, and assist users in making decisions and optimizing systems. The feedback mechanism of this process further strengthens the closed-loop collaboration between the virtual model and the physical entity, making the interaction between the virtual and real worlds more precise and efficient.

1.3 Application Needs and Challenges of Digital Twin Technology in Computer Science

The demand for the application of digital twin technology in the computer science curriculum is increasing, particularly in fields such as intelligent manufacturing, the Internet of Things, and automation control. As these fields require efficient data processing, real-time simulation, and system optimization, digital twin technology has become an essential tool for achieving interdisciplinary integration and systematic thinking. Students in computer science need to master the fundamental principles of digital twin technology, algorithm models, data analysis techniques, and system integration methods to effectively apply this technology in their future careers[2].

However, the learning and application of digital twin technology face several challenges. First, digital twin technology involves the integration of knowledge from multiple disciplines, including computer science, physics, mathematics, and engineering. Students must have a solid interdisciplinary background. Secondly, modeling and simulating digital twins typically require substantial computing resources and efficient algorithmic support, which sets high demands for students' technical implementation skills. Moreover, due to the rapid development of digital twin technology, new application scenarios and technical requirements are constantly emerging, and the traditional computer science curriculum system struggles to keep up with these changes, leading to outdated knowledge and higher technical difficulty for students. Additionally, the development of practical skills in digital twin technology relies on advanced teaching platforms and experimental resources, which many schools and institutions still fail to fully provide.

Therefore, how to effectively integrate digital twin technology into computer science teaching, and cultivate students' practical application abilities, has become an important issue in the current education reform and curriculum development.

2. Course Development Objectives and Framework Design for Digital Twin Technology

2.1 Course Objectives and Teaching Positioning

The objective of the digital twin technology course is to provide computer science students with a comprehensive learning framework that combines theory and practice. This will enable them to master the core concepts, working principles, key technologies, and application methods of digital twin technology. The course aims not only to help students understand the basic theory of digital twins and cultivate their systems thinking and interdisciplinary knowledge, but also to improve their practical abilities in digital twin system design, modeling, data analysis, and simulation prediction, particularly in related fields such as large-scale data processing, artificial intelligence, and the Internet of Things[3].

In terms of teaching positioning, the digital twin technology course should be integrated into the foundational curriculum of computer science majors, aiming to develop students' proficiency in advanced digital technologies and interdisciplinary application skills. The course content must not only align with the development trends of computer science and technology but also fully consider the current needs of industrial and technological sectors. It should cover the practical applications of cutting-edge technologies such as intelligent manufacturing, smart cities, the Internet of Things, and cloud computing. Through this course, students will gain an in-depth understanding of the practical operation and technical architecture of digital twin technology across various industries, cultivating their engineering practice abilities, innovative thinking, and interdisciplinary collaboration skills. Additionally, the course should emphasize systematic thinking training to enable students to apply the knowledge learned to solve complex engineering problems in their future careers, equipping them to meet new technological challenges and providing a solid theoretical and practical foundation for entering high-tech fields.

2.2 Course Content Structure and Modular Design

The design of the digital twin technology course content should follow the principles of modularity and hierarchy to ensure that students gradually master a complete knowledge system, from basic theory to application, during the learning process. The content structure of the course can be divided into four main modules: basic theory, key technologies, practical operations, and comprehensive applications.

The basic theory module primarily explains the basic concepts, development history, core components, and working principles of digital twins, with a focus on issues such as physical entity modeling, virtual model construction, data interaction, and real-time updates. By introducing the origins, development trends, and related technologies of digital twin technology, this module provides a theoretical framework to help students understand the fundamental operational principles of digital twin systems[4].

The key technologies module delves into the core technologies enabling digital twin technology, such as data collection and transmission, real-time data processing and analysis, virtual simulation and modeling, and artificial intelligence and big data algorithms. The goal of this module is to help students master relevant algorithms, tools, and platforms, enabling them to independently design and implement digital twin systems in practical projects.

The practical operations module promotes students' ability to translate theoretical knowledge into practical skills through experiments and project-driven learning. This module will involve students in the development and application of digital twin systems, from data collection and processing to virtual model construction, simulation, and optimization. Through case-based training, students will enhance their ability to solve engineering problems.

The comprehensive applications module combines the cutting-edge application fields of digital twin technology and incorporates interdisciplinary course design. In this module, students will encounter real-world case studies of digital twins in areas such as intelligent manufacturing, smart cities, and intelligent transportation, fostering their innovation abilities and engineering practice skills.

2.3 Teaching Resources and Platform Support

The effective delivery of the digital twin technology course relies on modern teaching resources and platform support. First, the course content needs to be backed by rich textbooks, reference materials, and the latest research results from both domestic and international sources to ensure that students receive up-to-date academic information and technological developments. Furthermore, since digital twin technology closely integrates theory and practice, the course should provide students with comprehensive experimental resources and engineering practice platforms.

In terms of experimental platforms, virtual simulation environments, cloud computing platforms, and IoT devices can be utilized to construct digital twin experimental systems based on real-world application scenarios. Through cloud platforms, students can access large-scale datasets and use cloud computing capabilities for efficient analysis and processing. Additionally, for data processing and analysis, the course should equip students with big data analysis tools, artificial intelligence algorithm libraries, and simulation tools to help them better design experiments and implement projects.

To further support teaching innovation, the course should offer online learning platforms and open-access teaching resource libraries, enabling students to engage in self-paced learning and review at any time. During the teaching process, online courses, videos, and interactive platforms can be used to assist teaching, providing after-class discussions, problem-solving, and case analyses, thus enhancing communication and interaction between teachers and students, as well as among peers[5].

Moreover, the digital twin technology course should rely on industry collaboration and enterprise resources to introduce real engineering projects and application cases, allowing students to gain practical experience in real-world project environments. This collaboration will not only enhance students' practical abilities but also help them understand industry needs and technological development trends, enabling them to better meet the demands of future job positions.

3. Innovative Teaching Methods and Effectiveness Evaluation in Digital Twin Technology Education

3.1 Design and Implementation of Innovative Teaching Methods

The teaching innovation in the digital twin technology course should closely align with the current trends in educational technology and meet students' learning needs. By designing diversified teaching methods, the course aims to enhance learning outcomes and students' practical abilities. First, the project-based teaching model is a key innovation for the digital twin technology course. In this model, students participate in the design and implementation of real-world projects, which enables them to gain a deeper understanding of the connection between theoretical knowledge and practical applications. Project-based teaching not only enhances students' hands-on skills but also stimulates their innovative thinking and problem-solving abilities. The course can include multiple project tasks, such as modeling, simulation, and optimization of digital twin systems, allowing students to collaborate in groups to complete tasks and develop teamwork and interdisciplinary problem-solving skills.

Second, the case-based teaching method effectively promotes students' understanding and application of complex concepts. Teachers can select typical digital twin application cases, such as production line optimization in intelligent manufacturing or traffic scheduling systems in smart cities, guiding students to analyze and discuss the technological implementations and problem-solving approaches in these cases. By analyzing real-world cases, students can transform theoretical knowledge into practical skills and cultivate critical thinking.

In addition, the flipped classroom, as an innovative teaching mode, has also been widely applied in the digital twin technology course. By shifting much of the lecture content to out-of-class learning, students engage more in interaction, discussion, and hands-on activities during class time, while teachers act as facilitators and collaborators, providing technical support and theoretical guidance. This method stimulates students' self-directed learning awareness and enthusiasm, promoting the depth and breadth of classroom learning[6].

Finally, the integration of virtual simulation platforms and experimental teaching is an important component of the innovative teaching in the digital twin technology course. Using virtual simulation platforms, students can simulate and test different scenarios of digital twin systems without the need for complex experimental equipment, conducting data analysis and optimization experiments to enhance their practical understanding of theoretical knowledge.

3.2 Construction of a Diversified Evaluation System

The evaluation system for the digital twin technology course should reflect its multidisciplinary and cross-disciplinary characteristics, focusing on the assessment of students' overall abilities, rather than just their grasp of individual knowledge points. Therefore, constructing a diversified evaluation system is particularly important. This system should include both formative and summative assessments, comprehensively measuring students' learning outcomes and ability development throughout the course.

Formative evaluation mainly focuses on students' participation and growth during the learning process, specifically assessing their performance in project tasks, teamwork ability, problem-solving skills, and innovative thinking. Teachers can evaluate students by observing their role distribution and performance in projects, team interaction and communication, and the quality of task completion. Additionally, classroom discussions, extracurricular assignments, and lab reports can be part of the formative evaluation to help teachers gain a comprehensive understanding of students' learning progress and practical abilities.

Summative evaluation focuses on students' overall performance at the end of the course, mainly through final exams, project outcomes, and reports. This evaluation system not only examines students' theoretical knowledge but also assesses their application abilities in real-world problems. For instance, in the final project presentation, students need to demonstrate their understanding and application of digital twin system design, implementation, and optimization schemes, thus evaluating their overall capabilities.

Furthermore, self-assessment and peer evaluation are also important components of the diversified evaluation system. Through self-assessment, students can reflect on their learning process, identify their strengths and weaknesses; through peer evaluation, students can evaluate their classmates' work, enhancing critical thinking and collaboration skills.

3.3 Feedback and Optimization Path for Teaching Innovation

The effectiveness of teaching innovation relies on continuous feedback mechanisms for assessment and optimization, ensuring the scientific and forward-looking nature of the course content and teaching methods. In the digital twin technology course, teachers should regularly collect students' feedback on course difficulty, content, experimental design, and evaluation methods. By using classroom surveys, online questionnaires, and teaching discussions, teachers can accurately identify the teaching challenges and knowledge gaps. Based on feedback data, teachers can dynamically adjust the course content and optimize teaching strategies to improve students' learning experience and knowledge acquisition. Additionally, by analyzing students' performance and learning outcomes on experimental platforms, the experimental teaching system can be further refined to ensure that practical components effectively support theoretical learning.

Apart from student feedback, peer review and industry practice should also serve as important bases for course optimization. Teachers can draw on advanced teaching experiences through academic seminars and interdepartmental exchanges to refine course design. At the same time, course content needs to closely align with industry development trends, incorporating the latest digital twin technology research outcomes and application cases, ensuring the practicality and cutting-edge nature of the teaching material. By collaborating with enterprises and inviting industry experts to give lectures, students can understand and apply what they have learned in real-world scenarios. Ultimately, through multidimensional evaluations of students' learning effectiveness, the teaching model can be continuously optimized, establishing a scientific, dynamic course optimization system to meet the rapid development of digital twin technology and the talent development needs of computer science majors.

Conclusion

This paper provides an in-depth analysis of the digital twin technology course development for computer science majors, proposing a systematic course framework that integrates innovative teaching methods and a diversified evaluation system to enhance students' theoretical knowledge and practical skills. However, with the continuous advancement of technology and the expansion of application scenarios, the teaching content and methods for digital twin technology must also be continually optimized. In the future, further improvements to the course should focus on integrating the latest industry trends and technological advancements, incorporating more interdisciplinary content to enhance students' innovation abilities and their capacity to solve complex engineering problems. Additionally, with the increasing maturity of virtual simulation technologies and big data platforms, the experimental platforms and resource support for the course should be further improved, providing more real-world projects and industry cases to enhance students' practical experience.

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