Journal of Electronic Research and Application, 2025, Volume 9, Issue 1
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Development of Intelligent Manufacturing Teaching and Training Platform Based on Digital Twin

Zizheng Zhao*, Xueqian Zou, Boyang Li

Shandong University, Jinan 250002, China

***Corresponding author:** Zizheng Zhao, zzz@sdu.edu.cn

Abstract: With the advancement and maturation of digital technology, immersive experiences, virtual interactive systems, and real physical environments are combined to create an independent "digital twin" world. In the field of intelligent manufacturing, there is a growing need to explore and develop a new platform for practical teaching based on digital twins, in line with the intelligent, networked, and digital transformation of education. By analyzing the design elements of this platform, building various digital twin prototypes and environments, and developing a teaching and training platform for intelligent manufacturing based on digital twins, significant improvements can be achieved in efficiency. Therefore, this paper discusses the development of an intelligent manufacturing teaching and training platform based on digital twins, aiming to enrich both the form and content of intelligent manufacturing training.

Keywords: Digital twin; Intelligent manufacturing; Teaching experiment; Training platform; Development strategy

Online publication: February 12, 2025

1. Introduction

At present, digital twin technology is becoming the new grasp of the global industry and education reform, and China has proposed to take it as a breakthrough and innovation of technical advantages in the 14th Five-Year Plan. With the promotion of "Made in China 2025," the traditional manufacturing industry has put forward more requirements for talent demand and talent training [1]. Due to the limitations of the objective environment, there are still many physical bottlenecks in the experiment and training teaching. Based on digital twin, developing an intelligent manufacturing teaching and training platform, supporting students' practical exploration by automated production line simulation and debugging comprehensive digital collaboration, and cultivating students' practical ability is the best way to break environmental restrictions. The digital twin technology puts forward a new solution for the reform and innovation of intelligent manufacturing and education, which adapts to the current social development needs and talent training needs and is worthy of our in-depth exploration and practice.

2. The composition of intelligent manufacturing teaching experiments and training system

The teaching and training content of intelligent manufacturing is composed of four elements, which are the physical layer, virtual layer, simulation software, and technical resources [2]. Among them, the physical layer is the ubiquitous mechanical structure, which is composed of transmission sorting, warehousing logistics, and pipeline product lines. The virtual layer is the data connection between equipment and application software. The simulation software layer is the simulation experiment software serving intelligent manufacturing, supporting diversified interactive operations and functions. Technical resources include all learning resources, including development engineering environment resources and curriculum resources [3]. With the combination of these four points, the function and value of the training platform can be fully brought into play, and the digital virtualization of production routes and fusion simulation training, as shown in **Figure 1** below. Based on practical training, students have a better understanding of the training content, to consolidate the theoretical foundation of the professional operation level and practical skills. Digital twin technology will also be integrated into advanced technology to achieve barrier-free data transmission and collection, and real-time online monitoring of the process, which can be said to kill many birds with one stone.

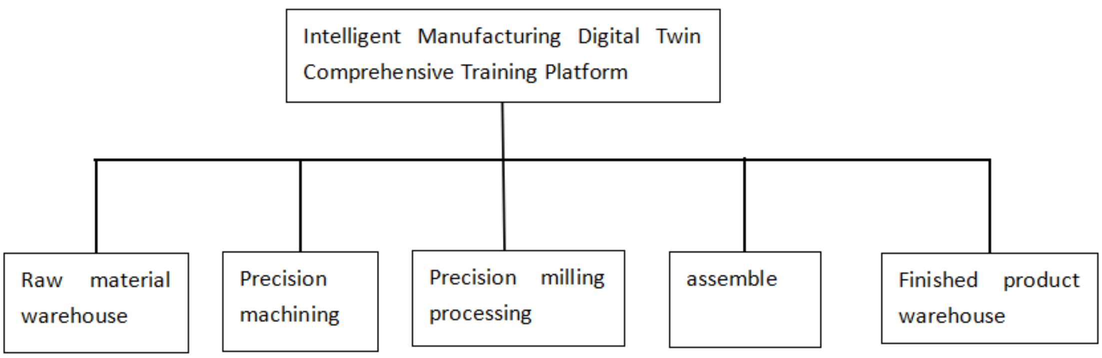

Figure 1. Intelligent manufacturing digital twin comprehensive training platform

3. The physical composition of the intelligent manufacturing teaching and training platform

3.1. Mechanical structure

The mechanical structure of intelligent manufacturing teaching and training platforms is an important basis for realizing intelligent manufacturing training and teaching. The composition of each module should have index parameters to complete its function. With the assistance of the vision system, the sorting module completes the integration of the workpiece sorting, transmission, and sorting according to the actual color, shape, and coding, and at the same time collaborates with other modules to complete the sorting task. The transmission module composed of a belt and motor is used to transmit objects. The transmission drive mode uses a three-phase alternate current (AC) speed regulation motor with start and stop and speed regulation functions, and realizes the additional function of detecting and blocking workpieces through photoelectric sensors and blocking devices [4–7]. In addition, the feeding, mechanical arm, transmission, warehouse, and other mechanical structures are important support for the virtual simulation experiment. These are important components of intelligent manufacturing teaching experiment training platform machinery and electrical control.

3.2. Electrical control system

The electronic control system of the intelligent manufacturing training platform is mainly through the setting of programmable logic controller (PLC) control mode, according to the work requirements of each unit to control the program and the execution of corresponding actions and operations [8]. PLC controls the three-coordinate robot, which can complete the workpiece handling of various routes. At the same time, it performs signal docking with the digital twin host through Profibus or Profinet to improve the function of the analog system [9]. On the one hand, the robot controller is docked with the PLC module, and on the other hand, it realizes the free control of the six axes of the robot to ensure the accurate movement of the robot. The control module is also docked with the PLC module to control the XYZ mobile module to achieve specific mobile functions. The digital twin host is also docked with the PLC module and the digital twin teaching display platform, which continues to dock multiple students' training computers, providing strong support for teaching and practical training [10]. In other words, the hardware cooperation and operation of the electronic control unit help the operation of various project tasks in the platform, and the control operation is realized through the virtual keys in the digital twin. This also facilitates the application of students, enables them to overcome fear, eliminates various risks caused by operation errors, helps to quickly verify ideas and skilled applications, and strengthens students' practical training skills [11].

4. Development and design of intelligent manufacturing teaching experiment training platform based on digital twin

4.1. Intelligent manufacturing digital twin comprehensive training platform

In engineering training teaching, the construction of a comprehensive training platform for intelligent manufacturing digital twin has far-reaching significance. Combining the project practice of intelligent manufacturing production line with digital twin technology, constructing virtual scenes and digital teaching platforms will bring students more novel experience and operational experiences [12]. In the design, through the production workshop or production line in the real world, a 1:1 size virtual scene is established to realize the synchronization of actions and information with industrial robot control, PLC control, automated guided vehicle (AGV) car control, and other actions in the real production workshop (production line) equipment. In the virtual scene, the training system covers multiple areas such as the raw material area, storage area, transmission area, finishing area, finishing milling area, assembly area, and finished product area. In the virtual scene, simulation is carried out to provide students with a highly realistic training environment [13]. Students can deeply understand all aspects of intelligent manufacturing through the virtual scene, from the storage and management of raw materials to the process of precision machining, and then to the assembly of products and the output of final products. Students can be familiar with the process and equipment operation in actual production in advance to improve their practical and problem-solving abilities. Students can observe and analyze the data in the production process in real-time, optimize the production process, and improve production efficiency.

4.2. Intelligent manufacturing teaching experiment and training platform function

The function development of the teaching and training platform based on digital twin technology is equally important, especially in the intelligent assembly area, which has strong adaptability. According to the current technology, real hardware PLC can be connected in this area, providing students with the opportunity to debug PLC input/output (I/O) signals online. Based on signal debugging, receiving, and sending I/O signals, students truly understand the internal logic operation of the system and operate the real-time signal change law on the PLC.

Of course, this is ubiquitous in the intelligent manufacturing experiment, and there is PLC control in each functional area. Once the students master the practical operation of the assembly area, they can extend to other PLC signals such as the raw material area, the finishing car area, the finishing milling area, and the finished product area. At the same time, the virtual AGV car will move to the corresponding position in the scene along the magnetic stripe trajectory in the virtual scene according to the signal input of the PLC, which effectively provides a highly realistic and functionally rich practical environment for students, so that they can deeply understand all aspects of intelligent manufacturing. Master the skills of PLC debugging, signal logic control, and the collaborative operation of virtual equipment and real hardware, and have a deeper understanding and feeling of intelligent manufacturing [14].

In the assembly area, the model of the virtual intelligent assembly area is highly restored, which is similar to the actual production and processing, which can be described as accurate reproduction. There are all kinds of accessories and fixtures involved in the processing in reality, and there are also corresponding models to choose from in the virtual world. At the same time, it also displays accurate actions such as the extension and retraction of the limited cylinder, the action of the robot jig to grab the material, and the operation of the screw machine, to help students practice operation more realistically. Like the real equipment, the intelligent manufacturing virtual system supported by the digital twin system can make corresponding changes by receiving real-time PLC signals [15]. With a high degree of synchronization and reduction, it provides strong support for the management and optimization of the whole intelligent manufacturing process. More intuitively understand the entire production line production process, identify potential problems in advance, and make adjustments to improve production efficiency and quality.

5. Concluding remarks

The intelligent manufacturing teaching experiment and training platform supported by digital twin has the characteristics of integration of theory and reality and a combination of virtual and real. It supports modern resource platforms and teaching conditions, provides the majority of students with new practical experience, and lays a solid foundation for their future academic research and employment. The platform has a complete simulation of the digital manufacturing process, virtual debugging, and judgment and verification of PLC logic signals, which meets the needs of teachers and students for real cases of enterprises, covering from simple production line unit equipment to automated production line, so that students can learn step by step. After learning professional theory content, students can periodically train and complete project tasks through the training platform, and integrate theoretical knowledge and practice, to better use professional skills and improve their innovation ability and competitiveness. In the future, the development of relevant platforms and the innovation of teaching models are still worthy of our attention and optimization.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Tian L, Bao Z, 2024, Research Analysis and Relevant Improvement Suggestions for Accounting Training Platform Under the Background of Data Intelligence. Accounting for Township Enterprises in China, 2024(06): 193–195.

[2] Lu D, 2024, Design of Digital Twin Simulation and Debugging Training Platform. Science and Technology Information, 22(04): 50–52.

[3] Yang B, Yu Q, Zhang D, 2023, Research on Virtual Simulation Training Teaching of Intelligent Production Line Based on Digital Twin Technology. Science and Education Guide, 2023(26): 46–49.

[4] Wei F, Zhang T, Luo P, 2022, Research on Online and Offline Training Teaching of Intelligent Manufacturing Based on Digital Twin—Taking Industrial Robot Assembly and Adjustment Training Course as an Example. Journal of Xichang University (Natural Science Edition), 36(04): 124–128.

[5] Xiao C, Yang X, Miao L, et al., 2021, Design and Implementation of Intelligent Manufacturing Comprehensive Training Platform for Metallurgical Industry Under the Background of New Engineering. Experimental Technology and Management, 38(12): 230–234 + 238.

[6] Ji Z, Fu X, Jiang D, 2021, Construction of Intelligent Manufacturing Comprehensive Training Platform Based on "Engineering and Management Integration". Experimental Technology and Management, 38(11): 254–259.

[7] Du P, Chen H, Jiang H, 2021, Construction of Multi-Party Collaborative Information and Electricity Cross Composite Practice Platform Under the Background of Intelligent Manufacturing. Journal of Experimental Technology and Management, 38(04): 30–35.

[8] Li GQ, Huang H, 2021, Research on the Construction of Intelligent Manufacturing Training Platform for Mold under the Background of Modern Apprenticeship Training—Taking Wuhan Vocational College as an example. Journal of Wuhan Metallurgical Management Cadre Institute, 31(01): 64–66.

[9] Yang M, 2020, Virtual-Real Combination Training Platform and Automation Teaching Integration to Improve the Quality of Talent Training. Labor Security World, 2020(06): 56.

[10] Zhou Y, Wang G, Wang Z, et al., 2019, Thinking on the Construction of Intelligent Manufacturing Training Platform for Petroleum Equipment under the Background of New Engineering. Contemporary Educational Practice and Teaching Research, 2019(16): 222–223.

[11] Chen GC, Zhang LF, Wu YJ, et al., 2018, Development of High-Quality Teaching Resources of Spinning Process Design and Quality Control Based on Cloud Training Platform. Textile Industry and Technology, 47(10): 46–48.

[12] Qi X, 2018, Discussion on the Construction of Simulation Law Enforcement and Case Handling Area Training Platform for Investigation Science Major—Taking Xinjiang Police Academy as an Example. Journal of Xinjiang Police Academy, 38(03): 59–64.

[13] Zhang B, Wang R, Li S, 2018, Research and Exploration on the Construction of Industry-Education Integration Training Platform for Group Intelligent Manufacturing of Mechanical and Electrical Majors. Journal of Taizhou Vocational Technical College, 18(01): 7–9.

[14] Zhang L, 2015, The Information-based Teaching Design of Computer Courses in Higher Vocational Colleges—Taking "Common Problems and Countermeasures of the Installation of ERP Software Development Training Platform" as an Example. China Education Informationization, 2015(06): 46–48.

[15] Wu Z, Liang C, 2014, Research on the Construction and Implementation Strategy of Dual Platform of Logistics Management Professional Training in Higher Vocational Colleges Based on Information Characteristics—Taking Guangdong Vocational College of Science and Trade as an example. Logistics Engineering and Management, 36(11): 209–212.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.