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Research on Digital Twin Technology and Application in Campus

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Abstract: *With the continuous development of the science and technology, driven by the emerging industrial information systems and industrial intelligence, the digital twin technology has become a new research hotpot. In view of this, the basic concepts, application prospects, technical connotations and development trends of digital twin technology, as well as the existing preliminary research plans and the phased achievements are reviewed. The digital twin technology system, key technologies, development trends and technical challenges in the field of campus oriented intelligent operation and maintenance are summarized. It is expected to provide some references for the application of digital twin technology in campus.*

Keywords: *Industrial Intelligence; Digital Twin; Campus Applications*

1. Introduction

In recent years, the digital twin technology has become a research hotpot for scholars, research institutions and enterprises at home and abroad. Gartner, the world's most authoritative research and consulting company, has listed digital twin as one of the top ten strategic technology development trends for the four consecutive years since 2016. Since the introduction of the concept of digital twins in the space technology roadmap by the National Aeronautics and Space Administration (NASA) in 2010, the foreign research institutions and enterprises such as the Air Force Research Laboratory, Lockheed Martin, Boeing, Northrop Grumman and General Motors have actively researched and explored digital twins in the field of aerospace. Domestic research scholars have also conducted a large amount of research on digital twin technology. The academic community has held academic conferences on digital twin every year since 2017. The China Institute of Electronic Information Industry Development, the China Institute of Electronic Technology Standardization and the Industrial Internet Industry Alliance, affiliated to the Ministry of Industry and Information Technology of the People's Republic of China, have respectively issued "Digital Twin White Papers", "Digital Twin Application White Papers" and "Industrial Digital Twin White Papers". To consolidate and deepen the consensus on digital twin technology, it accelerated the innovation and application practice of digital twin technology.

With the continuous development of digital technology, it has gradually become a new technology in the field of campus. Digital twin technology can digitize the physical world, replicate and simulate physical entities through the virtual simulation technology, providing many possibilities for fields such as campus education, architecture, and equipment maintenance [1]. For example, digital twin technology can provide students with a more realistic teaching environment, help architects and campus managers better design and plan campus buildings and improve the efficiency of equipment maintenance and repair [2]. This article will summarize the application of digital twin technology in the campus, explore the advantages and the challenges of the digital twin technology in campus and propose the issues and challenges that need the attention while applying the digital twin technology.

2. Research Status of Digital Twin

2.1. Definition of Digital Twin

Digital twin refers to the establishment and simulation of a physical entity, process, or system within an information platform. With the help of Digital Twin, it is possible to understand the state of physical entities on an information platform and control predefined interface elements within physical entities. Digital Twin is a concept within the Internet of Things, which integrates physical feedback data,

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supplemented by artificial intelligence, machine learning, and software analysis, to establish a digital simulation within an information platform. This simulation will automatically make the corresponding changes as physical entities change based on feedback. Ideally, digital twins can self-learning based on multiple feedback source data, presenting the true state of physical entities in the digital world in almost real-time. The feedback source of Digital Twin mainly relies on various sensors, such as pressure, angle, and speed sensors. In addition to relying on feedback information from sensors, digital twin self-learning or machine learning can also rely on historical data or data learning through the integrated networks. The latter often refers to multiple physical entities in the same batch performing different operations at the same time, and feeding back data to the same information platform. Digital Twin conducts rapid in-depth learning and accurate simulation based on massive information feedback [1-2].

2.2. Researches of Digital Twin

Digital twins are generally believed to be a concept proposed in the course of "Product Lifecycle Management" in 2002 by Dr. Michael Grieves, a professor at the University of Michigan in the United States. They were initially named "Information Mirroring Model", and later evolved into "Digital Twins" [3]. Initially, this concept was used to refer to the digital representation of products used in simulation software, but now it has been expanded to the concept of not only representing physical products in virtual form of software, but also directly connecting each product to a virtual counterpart digital twin.

By 2015, the explosive growth of machine learning, wireless communications, and cloud computing has driven the research activities for the digital twin. Tao and the other scholars [4] believe that digital twins enable the manufacturers to make more accurate predictions, reasonable decisions, and wise plans. They believe that digital twins may trigger the next wave of the simulation technology development. So far, the development of simulation has gone through the three stages: first, the simulation of the specific devices based on the special tools; second, the simulation of general equipment based on the standard tools; third, the multilevel, multidisciplinary simulation. The emergence of digital twins provides the exciting possibilities for the real-time simulation throughout the product life cycle.

Since then, the different scholars have proposed the different perspectives on the research methods of digital twin technology. Weyer and the other scholars [5] believe that the research on digital twin should focus on multidisciplinary collaborative simulation. As today's products become increasingly complex and product life cycles shorten, the use of simulation tools to optimize and accelerate the various stages of the production life cycle becomes increasingly important. However, while fully utilizing the potential of the simulation technology in the smart factories, many unprecedented challenges arise. It proposes a conceptual framework aimed at overcoming current technical barriers in the fields of digital continuity, real-world synchronization, and multidisciplinary research. Each architectural component of the architecture will be implemented as a service to promote the reuse and separation of concerns.

Qi and the other scholars [6] consider digital twins can enable the manufacturers to manage the real-time and bidirectional mapping between physical objects and digital representations, paving the way for the network physical integration. In this document, it is also proposed that the digital twin technology can be combined with the precise analysis and prediction functions of big data, and the intelligent manufacturing driven by digital twin will become more responsive and predictive, and in many aspects will be conducive to more reasonable and accurate manufacturing management. It is believed that digital twins and big data can complement each other well to help the development of the intelligent manufacturing.

Other scholars believe that digital twin is a method to achieve the fusion of physical space and virtual space [3]. It pointed out that the digital twin technology can be applied in three stages of the product life cycle, including the product design driven by digital twinning, the product manufacturing driven by digital twinning, and the product services driven by digital twinning. In addition to its application in production, digital twins have gradually emerged in the field of industrial control network security in the recent years.

Christian and Martin [7] studied a scheme to ensure the security of industrial control systems based on digital twin technology. They introduced a new attack model, proposed a basic security definition, determined the security requirements, and finally proposed a novel security architecture, mainly a state replication model for industrial control systems based on digital twins. In addition, a preliminary security assessment was conducted for the new state replication model and architecture based on the identified requirements. The authors have conducted preliminary discussions on the intrusion detection, access control, and formal security analysis based on the proposed state replication scheme, but have not yet

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conducted actual design and experiments.

Murillo and Rueda [8] have deeply studied the application of digital twins in industrial control network security from the perspective of access control, proposed a lightweight access control framework for the digital twins of industrial control systems, provided a language for defining the access control policies for them, and implemented a proof of concept using OpenStack. The results indicate that the developed policy language can describe the components and relationships established in the digital twins of industrial control systems, and then use these relationships to define the access control rules.

Xu et al. [9] proposed a two-stage deep transfer learning method that combines deep transfer learning and digital twins to improve the transparency, flexibility, and efficiency of the fault diagnosis. This method simulates the evolution and recovery of faults in an abstract and visual manner. It can well handle the following two problems: the problem of insufficient training data during the initial stage of production and the problem of large differences in data distribution under changing working conditions. Moreover, it extends the diagnostic service cycle from the production process to the entire product life cycle.

During the development phase, the Digital Twin aims to identify and repair the potential design defects and obtain the excellent diagnostic models. Then, during the operation and maintenance phase, the knowledge learned from the simulation is transferred from virtual space to physical space, without the need to train the model from scratch. Through the dual fault diagnosis in virtual space and physical space, the risk of the unexpected failures is greatly reduced, which may make the intelligent manufacturing sustainable, reliable and efficient. Eckhart and Ekelhart [10] believe that digital twins have opened up the new possibilities in the monitoring, simulating, optimizing and predicting the state of Cyber Physical Systems (CPS), and that CPS's fully functional virtual replicas also play an important role in protecting the system security. It proposed a framework that allows the users to create and execute digital twins that closely match their industrial control devices. Using this framework, you can freely explore and test exactly the same simulate the environment based on the system's specifications without adversely affecting the real-time system. Further, the security module at the top of the framework also supports security analysts to monitor the current state of the CPS or perform security analysis. Specifically, the users can declare security rules implicitly or explicitly. After the security module extracts these rules from the specifications, it will perform analysis during operation to detect abnormalities in the process in the virtual environment status. In addition to detecting abnormal process states during operations, this module also provides the possibility of the running simulations in a virtual environment to test whether the settings violate specified rules.

3. Application and Prospect of Digital Twins in Campus

3.1. Application Status

Digital twin technology has been widely used in many fields, such as industrial manufacturing, construction and urban planning, energy, medical care, agriculture, education, and entertainment [11-12].

In industrial manufacturing, digital twin technology is used for product design, production process optimization, and quality management in the manufacturing industry. Through digital twin technology, the manufacturers can design and test products in a computer-simulated environment, and optimize production processes to improve production efficiency and product quality.

In architecture and urban planning, digital twin technology is used for design, construction, and facility management in architecture and urban planning. Through digital twin technology, architects and urban planners can design and test building and urban planning solutions in a computer-simulated environment, and optimize the sustainability and efficiency of buildings and cities.

In the energy field, the digital twin technology is used for equipment monitoring, operation optimization and troubleshooting in the energy field. Through digital twins, the energy companies can create the digital copies of devices, monitor their performance and health, and predict the device failures. It helps improve the reliability and the efficiency of the energy equipment, reducing downtime and maintenance costs.

In medicine, digital twins is used for the surgical simulation and the human organ simulation. Through the digital twin technology, doctors can simulate the surgical process and optimize the surgical plan in a computer simulation environment. In addition, the digital twin technology can also be used to develop and test medical devices to improve their safety and efficiency.

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In agriculture, digital twins is used for the crop growth simulation, the soil analysis and the irrigation optimization. By the digital twin technology, the agricultural producers can create the digital models of the crop growth and make the optimal decisions based on these models to improve the crop yield and quality.

In education and entertainment, digital twins is used for virtual experiments and game development in the corresponding field.

3.2. Development Prospects

The digital twin technology has gradually been integrated into people's lives, bringing them a better life experience. Of course, we can consider deeply integrating the digital twin technology with the field of the education. Through the digital twin technology, the teachers and students can create the realistic virtual environments and conduct teaching in them, which can help provide a more realistic user experience and enhances the attractiveness of students to learning. Education and the digital twin technology can be integrated from the following aspects:

The digital twin technology in facility management can establish a digital model of campus buildings. Through real-time monitoring and data analysis, it can predict and optimize the use of buildings, energy consumption, equipment operation status, etc., improving the use efficiency of facilities and reducing costs [13-15].

In education and teaching, the digital twin technology can simulate the classroom, laboratory, studio, and other scenarios, providing a visualized teaching environment, helping the students better understand and master the knowledge, practice skills, and improve the practical abilities. At the same time, the digital twin technology can also achieve the personalized teaching, providing the customized learning content and programs based on the students' learning situations and interests.

The digital twin technology in the campus security can improve the early warning and emergency processing capabilities of the campus security and reduce the occurrence of campus security incidents by establishing a digital model of the campus security, including monitoring the equipment, alarm systems, emergency rescue, etc. through the data analysis and simulation [14].

The digital twin technology in student management can establish a digital twin model for students, including personal information, learning situations, behavioral habits, etc. Through data analysis and mining, it can better understand students' needs and problems, and provide personalized services and support [16].

In summary, digital twins has a broad application prospect in the field of campus, which can improve the management efficiency, the teaching quality, and the student service level of the campus, as well as improve the security guarantee ability of the campus. With the continuous development and maturity of the digital twins, it is believed that its application in the field of the campus will be more and more widely promoted and applied.

4. Advantages and Challenges of Digital Twins in Campus

In this article, the combination of the campus and the digital twin technology is mentioned in the outlook. The following will specifically analyze the advantages and challenges of the application of digital twin technology in campus.

4.1. Application Advantages

The deep integration of the digital twin technology and campus will greatly improve the efficiency of campus management. Digital twin technology can monitor and manage various facilities and resources on campus in real time, such as campus buildings, classrooms, libraries, parking lots, cafeterias and etc.

Through the digital twin technology, the automated and intelligent management can be achieved, improving the efficiency of the campus management. Campus services can also be optimized. The digital twin technology can match the needs of the users such as the students, faculty and other resources on the campus, which can achieve the optimization of campus services. For example, in the digital twin model, it is possible to query the classroom usage and parking space allowance in real time, which can help users better arrange the time and resources.

On this basis, it can also reduce the operating costs of the campus[17-18]. Digital Twins can monitor and predict the use of the campus resources in real time. It may help the campus managers better plan and optimize the use of resources, thereby it can reduce the operating costs of the campus.

4.2. Problem Challenges

The combination of the digital twin technology and the campus has many advantages, but we also face many challenges. It is hoped that researchers in the field of the data twinning technology in the future can overcome the following challenges one by one.

The first thing to consider is data security. Digital Twins technology requires a large amount of data input and processing, so the data security issues become an important challenge. Campus needs to take strict security measures to ensure that the data in the digital twin model is not compromised or attacked.

Secondly, there is the issue of resource investment. Digital twin technology requires a large amount of capital, technology, and human investment, which may be a challenge for some schools with the relatively limited resources. Campus needs to balance the relationship between investment and revenue, and reasonably plan the construction and operation of digital twin technology.

Finally, there is the issue of the demand change [19-20]. The needs of the campus are constantly changing over time and users. The digital twin model needs to be constantly updated and optimized to adapt to the changing needs. It requires a large amount of the manpower, time, and resources on campus to maintain the sustainable development of the digital twin model.

5. Conclusions

The concept of digital twins has the important implications for promoting the intelligent manufacturing and the digital transformation. From its conceptual connotation and key technology analysis, it can be seen that the digital twinning technology has a wide range of the applications and potential on the campus, which can provide the better tools and resources for the school planning, management and education, help the students and faculty better explore and utilize the campus resources, and improve the school efficiency and security. Although the digital twin technology has many potential and applications on the campus, it is still necessary for the schools to fully consider their technical, management, security, economic issues and challenges while applying the digital twin technology, in order to ensure that the application of the digital twin technology can truly bring the practical benefits and provide the schools with better education and management tools.

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References

[1] Nie Rongmei, Zhou Xiaoya, Xiao Jin, et al Overview, Analysis and Development Prospect of Digital Twin Technology [J]. Aerospace General Technology, 2022,6 (1): 6.
[2] Liu Datong, Guo Kai, Wang Benkuan, et al Overview and Prospect of Digital Twin Technology [J]. Journal of Instrumentation, 2018, 39 (11): 10.
[3] Grieves M. Digital twin: manufacturing excellence through virtual factory replication [J]. White paper, 2014, 1: 1-7.
[4] Tao F, Zhang H, Liu A, et al. Digital twin in industry: State-of-the-art[J]. IEEE Transactions on Industrial Informatics, 2018, 15(4): 2405-2415.
[5] Weyer S, Meyer T, Ohmer M, et al. Future modeling and simulation of cps-based factories: an example from the automotive industry [J]. Ifac-Papersonline, 2016, 49(31): 97-102.
[6] Qi Q, Tao F. Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison [J]. Ieee Access, 2018, 6: 3585-3593.
[7] Gehrmann C, Gunnarsson M. A digital twin based industrial automation and control system security architecture [J]. IEEE Transactions on Industrial Informatics, 2019, 16(1): 669-680.
[8] Murillo A F, Rueda S. Access control policies for network function virtualization environments in industrial control systems[C]. 2020 4th Conference on Cloud and Internet of Things (CIoT), 2020: 17-

ISSN 2616-7433 Vol. 5, Issue 5: 118-123, DOI: 10.25236/FSST.2023.050519

24.
[9] Xu Y, Sun Y, Liu X, et al. A digital-twin-assisted fault diagnosis using deep transfer learning [J]. IEEE Access, 2019, 7: 19990-19999.
[10] Eckhart M, Ekelhart A. Towards security-aware virtual environments for digital twins[C]. Proceedings of the 4th ACM workshop on cyber-physical system security, 2018: 61-72.
[11] Wu Yan, Wang Xiaojun, He Yong, et al Overview of key technologies and applications of digital twins in manufacturing industry [J]. Modern Manufacturing Engineering, 2021 (009): 000.
[12] Lu Jinling, Yan Luhan, La Zhiyuan, Liu Xiaopeng, Ren Hui. Real-time optimal scheduling strategy for integrated energy systems based on digital twins and dynamic energy efficiency models [J]. Grid Technology, 2023, 47 (01): 226-238.
[13] Wang Yiru. A three-dimensional campus vehicle roaming system based on digital twins [J]. Computer Knowledge and Technology, 2022, 18 (06): 94-96.
[14] Liu Xiaoxia. Research on campus security system dedicated LAN communication system [J]. Changjiang Information Communication, 2022 (007): 035.
[15] Chen Lei. Research on the Intelligent Party Building System in Universities Based on "Digital Twin+Artificial Intelligence" [J]. Modern Educational Technology, 2022, 32 (4): 7.
[16] Li Haifeng, Wang Wei. Research on the Teaching Model of Digital Twin Education Application -- Based on the Case Analysis of Digital Twin Education Application in the United States, Switzerland, and Finland [J]. Modern Educational Technology, 2021, 31 (7): 9.
[17] Sun Tingting, Xu Qian, Luo Chenyu. The Application of Digital Twin Technology in Campus Management [J]. Education and Teaching Forum, 2020 (28): 131-132.
[18] Yang Xiaoqing, Chen Zhuojun. Research on the Application of Digital Twin Technology in Campus Security [J]. Modern Educational Technology, 2020 (11): 45-49.
[19] Chen Siwen, Yu Min. Application and Research of Digital Twin Technology in Campus Intelligent Construction [J]. Information Education, 2020 (10): 36-38.
[20] Wang Wei, Wang Dan. The application of digital twin technology in campus intelligent construction [J]. Modern Educational Technology, 2021 (2): 53-55.