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Digital Twin Technology of Metaverse Based on Game Engine in the Campus Application Scenarios

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Abstract: *With the rapid development of industrial information technology and intelligence, the digital twin technologyofthe metaverse has been widely applied in various fields. This article focuses on the application of metaverse digital twin technology in campus scenarios, combining game engine technology and metaverse concepts to develop a metaverse digital twin system suitable for campuses. The definition of the concept of the metaverse, the application of digital twin technology in metaverse technology, and the role of game engines in it are explored. By analyzing the application scenarios of campus themes, it aims to provide the advanced management tools, the innovative teaching methods and the efficient campus services for the campus environment. Ultimately, it will discuss the technological advantages and potential challenges, which can provide guidance for the future research and practical applications.*

Keywords: *Metaverse; Digital twin; Game engine; Campus application*

1. Introduction

With the rapid development of technology, metaverse technology, as a cutting-edge technology leading the trend, has emerged in multiple fields such as industry and education. It provides new solutions for various industries by simulating real-world processes and systems in virtual environments. At the same time, the concept of the meta universe was put forward under the rapid development of the Internet and transmission technology, which has a natural high degree of consistency with the digital twin technology. Among numerous application fields, campus scenes have attracted much attention due to their complexity and diversity. The application of the concept of metaverse and digital twin technology in campus, especially in combination with game engine technology, provides a remarkable opportunity for building a campus metaverse digital twin system.

This article aims to explore in depth the metaverse digital twin technology based on game engines, using campus application scenarios as an example. We will analyze the core concepts of metaverse digital twin technology and combine it with game engine technology to develop a metaverse digital twin system with broad application prospects in campus environments. Through the study of campus theme application scenarios, we hope to provide innovative solutions for campus management, education and service optimization.

In this article, it firstly introduces the basic concepts and technical connotations of digital twin technology in the metaverse, and then explores the role of game engine technology in the metaverse. Next, it will focus on campus application scenarios and analyze the potential applications of metaverse digital twin technology in campus environments, while aiming to provide new ideas and methods for campus digital transformation. Finally, it will discuss the advantages, challenges, and future research directions of technology, as well as the current applications and prospects of metaverse digital twin technology in campus, whileproviding a comprehensive perspective for promoting the application and development of metaverse digital twin technology in the field of campus.

2. Metaverse Digital Twin Technology

2.1 Definition of Metaverse Digital Twin Technology

Metaverse digital twin technology is an advanced digital simulation technology that simulates,

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monitors, and analyzes physical entities in virtual space by creating precise digital copies of them. These digital replicas are called "digital twins" or "digital twins", and they can update and synchronize the status information of entities in real time, thereby reflecting the changes in the physical world in the virtual world. Currently, the metaverse integrates technologies such as the Internet of Things, virtual real interaction, blockchain, cloud computing, 5th Generation Mobile Communication Technology (5G), artificial intelligence (AI), and digital twins. Among them, the Internet of Things provides information sources; Virtual real interaction technology provides an immersive experience; Building a virtual and real economic system using blockchain technology; Cloud computing and 5G provide underlying infrastructure; Artificial intelligence provides the intelligent core of the metaverse; Digital twin technology achieves real-world mapping and is the core technology for constructing the metaverse. The metaverse itself is not a technology, but a technology integrated from a large number of modern technologies. Digital twin, as one of the key technologies in the metaverse, is a universal theoretical and technological system that utilizes physical models and sensors to collect various real-time data, complete the mapping from real space to virtual space, and reflect the lifecycle process of the corresponding entity through simulation and intelligent optimization algorithms.

The proposal of the metaverse signifies that human technological civilization has entered a new era, a new field that encompasses digitization, virtualization, and real-world interaction. Its concept is no longer limited to the fantasy of science fiction, but has become possible with the support of contemporary technology. With the outbreak of the epidemic, people's online activities have reached unprecedented heights. From social interaction to work and learning, almost all activities have shifted to the online space. This phenomenon is not only temporary, but also a part of people's lives. In 2021, Facebook changed its name to "Meta", announcing its ambition to enter the metaverse. This move is not only a company name change, but also a formal recognition and leadership of the concept of the metaverse. The metaverse is not a manifestation of a single technology, but a comprehensive application of multiple cutting-edge technologies. The integration of augmented reality technology, blockchain, cloud computing, and digital twins provides technical support for the construction of the metaverse. In this new virtual space, people can interact with the real world, creating, learning, and entertaining everything.

On September 13, 2022, the National Science and Technology Terminology Approval Committee held a seminar on the concept of the metaverse and core terminology. Experts and scholars delved into the essence of the metaverse and its related concepts. After thorough discussion, a consensus has been formed on the name and definition of the concept of "metaverse", which is defined as "a virtual world constructed by humans using digital technology that maps or transcends the real world and can interact with the real world" [1]. This consensus marks the transition of the metaverse from theoretical concepts to practice, becoming an important milestone in the development of human technology. Digital twin technology provides a realistic simulation of physical objects for the metaverse, establishes virtual digital spaces corresponding to real campuses, realizes dynamic interaction between physical and digital spaces, constructs virtual digital humans, and enables managers, educators, service providers, and learners to manage, serve, and teach campuses from a subjective perspective of ownership consciousness.

2.2 Current Research of Metaverse Technology

The term "metaverse" originated from the science fiction novel "Avalanche" in 1992. The novel mentions the concepts of "Metaverse" and "Avatar". People can have their own virtual avatars in the Metaverse, and this virtual world is called the Metaverse. In the novel "Real Name and Surname" published in 1981, a creative idea was conceived of a virtual world that can be accessed and experienced through a brain computer interface. A large number of open multiplayer games emerged from the 1970s to the 1990s, and the open world of the games themselves formed the early foundation of the metaverse. 2021 is the first year of the metaverse. At the beginning of 2021, Soul proposed building a "social metaverse" within the industry. In March 2021, Roblox, known as the first stock of the metaverse, was officially listed on the New York Stock Exchange. In May 2021, Microsoft CEO Satya Nadella stated that the company is working hard to create an "enterprise metaverse.". In June 2021, the world's first AI artificial intelligence digital shadow puppet collection was launched in the metaverse. In August 2021, Haier released the first intelligent manufacturing metaverse platform in the manufacturing industry, achieving the integration of physical and virtual intelligent manufacturing, and integrating a cross scenario experience of "factory, store, and home". In August 2021, Nvidia announced the launch of the world's first simulation and collaboration platform that provides the foundation for the establishment of the metaverse. On December 21, 2021, Baidu's first domestically

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produced metaverse product "Xirang" officially opened for targeted internal testing. Users can enter the Xirang space with an invitation code for advanced experience. On December 27, the Baidu Create AI Developer Conference was held on the "Xirang APP", which is the first conference held in China in the metaverse and can accommodate 100000 people to interact on the same screen at the same time. On April 26, 2022, at the China Metaverse Industry Development Summit Forum, the Chongqing Metaverse Pilot Zone was officially unveiled. On May 9, 2022, the Seoul City Hall of the Metaverse was opened to the public. On November 10, 2022, the first "Metaverse City Experience Hall" in China made its debut in Wuzhen. On May 5, 2023, the Metaverse Industry Alliance was established in Dongcheng District, Beijing. On August 29, 2023, the Ministry of Industry and Information Technology, the Ministry of Education, the Ministry of Culture and Tourism, the State owned Assets Supervision and Administration Commission of the State Council, and the State Administration of Radio and Television jointly issued the "Three Year Action Plan for Innovation and Development of the Metaverse Industry (2023-2025)".

On January 30, 2024, the 2023 China Metaverse Industry White Paper was released in Beijing. On February 1, 2024, Wu Gaobin, Secretary General of the Metaverse Committee (Preparatory) of the World Academy of Digital Technology and Secretary General of the Metaverse Working Committee of the China Association of Private Science and Technology Practitioners, believed that the metaverse, as an advanced form of digital and real integration, can promote the development of new economy, new formats, and new models, and can serve as a lever and engine for new productive forces, helping to promote high-quality economic development in China. Gather.town is a metaverse platform with teaching functions, where students can independently create virtual images to participate in teaching activities. Virtual teaching scenes can be arranged according to user needs; The extracurricular activity platform supports various virtual interactive activities, and the rest space can provide students with opportunities to interact and exchange ideas with other team members or classmates. In addition, many offline activities can be "moved" onto the platform. The Virtual STEM course at Nagaoka University of Technology and Science in Japan is a virtual platform created through technologies such as VR, AR, and XR. In the platform, teachers and students conduct teaching and learning through their respective terminals, and the resources, data, works, etc. generated throughout the model are recorded and transmitted in real-time to the teacher's terminal for management. The University of Cincinnati in the United States has established the Simulation and Virtual Environment Research Center, building a learning platform for the metaverse and offering courses in different fields to promote immersive learning. The most distinctive aspects are its research in the fields of healthcare and biotechnology.

Metaverse technology digitizes the data of the campus real world through simulation and simulation, achieving virtualization of the campus real world. The immersive and subjective management of the campus from an immersive perspective is unable to provide timely decision support due to delayed feedback, which makes it difficult to achieve the precise management and real-time monitoring of global trends in the multiple business scenarios. Through virtualization, various data on campus can be more finely managed and controlled, and various security risks and abnormal situations on campus can be detected in a timely manner. By visualizing data, campus management efficiency, decision-making quality, and information management level can be improved.

2.3 Current Research of Digital Twin Technology

Digital twins are generally believed to be a concept proposed by Dr. Michael Grieves, a professor at the University of Michigan in the United States, in 2002. In the initial "Product Lifecycle Management" course, this concept was initially referred to as the "Information Mirroring Model" and later evolved into the "Digital Twin"[2]. Initially, this concept was used to describe the digital representation of products in simulation software, but now it has expanded to not only represent physical products in virtual form (software), but also to directly connect each product to the corresponding digital twin of the virtual.

By 2015, the rapid growth of machine learning, wireless communication, and cloud computing had driven research activities on digital twins. Tao et al. [3] believe that digital twins enable manufacturers to make more accurate predictions, rational decisions, and wise plans. They believe that digital twins may trigger the next wave of simulation technology development. Subsequently, different scholars proposed different views on the research methods of digital twin technology. Weyer et al. [4] advocate that research on digital twins should focus on multidisciplinary collaborative simulation, while Qi et al. [5] believe that digital twins and big data can complement each other and contribute to the development of intelligent manufacturing. Some scholars believe that digital twins are a method of integrating physical space and virtual space. Christian and Martin [6] studied a scheme based on digital twin

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technology to ensure the security of industrial control systems, introduced a new attack model, proposed a security definition for the state replication model of industrial control systems based on digital twins, determined security requirements, and finally proposed a novel security architecture.

Murillo and Rueda [7] conducted in-depth research on the application of digital twin technology in industrial control network security from the perspective of access control, proposed a lightweight access control framework for digital twins in industrial control systems, and implemented concept verification using OpenStack. Their research indicates that the developed strategy language can describe the components and relationships established in the digital twin of industrial control systems, and use these relationships to define access control rules. Xu et al. [8] proposed a two-stage deep transfer learning method combining deep transfer learning and digital twin technology to improve the transparency, flexibility, and efficiency of fault diagnosis.

Digital twin is a concept in the field of the Internet of Things, which integrates physical feedback data, combines artificial intelligence, machine learning, and software analysis to create a digital simulation on an information platform. This simulation will quickly respond to changes in physical entities based on feedback. In an ideal scenario, digital twins can learn from multiple sources of feedback data and display the real state of physical entities in the digital world in real time. The feedback source of digital twins mainly relies on various sensors, such as pressure, angle, speed sensors, etc. The machine learning of digital twins can not only be based on feedback information from sensors, but also utilize historical data or network integrated data for learning. The latter usually refers to multiple similar physical entities performing different operations simultaneously and feeding data back to the same information platform. Digital twins perform deep learning and accurate simulation based on a large amount of information feedback [9-10].

In the development phase, the digital twin aims to discover and repair potential design defects and obtain excellent diagnostic models. In the operation and maintenance phase, the knowledge learned from simulation can be transferred to the physical space without retraining the model. By dual fault diagnosis in both virtual and physical spaces, the risk of unexpected failures is greatlyreduced, making intelligent manufacturing sustainable, reliable, and efficient. Eckhart and Ekelhart [11] believe that digital twins have opened up new possibilities in monitoring, simulating, optimizing, and predicting the state of network physical systems (CPS), and CPS's fully functional virtual replicas also play an important role in protecting system security. They proposed a framework that allows users to create and execute digital twins that closely match industrial control devices, allowing them to freely explore and test identical environments without causing negative impacts on real-time systems. The security module at the top of this framework supports security analysts to monitor the current status of CPS or conduct security analysis. Users can implicitly or explicitly declare security rules, and the security module extracts these rules from the specification and performs analysis during the operation to detect abnormal situations in the process in the virtual environment. In addition to detecting abnormal process states during operation, this module also provides the possibility of running simulations in a virtual environment to test whether the settings violate specified rules.

3. Advantages and Challenges of Metaverse Digital Twin Technology in Campuses

The development of this project is an application thatcombines campus scenarios with metaverse digital twin technology. Below, it will analyze in detail the advantages and challenges that metaverse technology and digital twin technology under metaverse technology have when applied and promoted on campus.

3.1 Advantages

3.1.1 Real Time Simulation and Optimization

Metaverse digital twin technology can simulate various scenarios on campus in real-time, including classrooms, laboratories, libraries etc. for optimization and improvement. The metaverse virtual teaching equipment can solve the problems of expensive physical teaching equipment, large land occupation, and environmental requirements of the venue [12], and improve the efficiency of the use of education funds for various majors. This helps to improve teaching effectiveness and campus management efficiency.

3.1.2 Virtual Learning Environment

Metaverse technology can create virtual learning environments, providing a more vivid, interactive, and personalized learning experience. Digital virtual teaching equipment can comprehensively simulate physical devices, allowing students to use virtual teaching equipment for practical training operations

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[12], master the skills and knowledge learned, and improve the teaching quality of various majors. Students can conduct experiments and simulation operations through metaverse digital twin technology, enhancing their understanding of various disciplines. Its positive effect will be particularly evident for subjects such as physics and chemistry that require experimental teaching. By utilizing metaverse technology, teaching content, scenes and characters can be presented in a three-dimensional virtual form, providing students with an immersive learning experience. This experience allows students to participate in various teaching activities in a virtual environment, such as lectures, discussions, experiments etc. to improve learning effectiveness. The biggest advantage of this method is that students can transcend two-dimensional constraints and freely navigate and locate in three-dimensional space. At the same time, it can self-track and unfold corresponding learning scenarios or spatial images based on independent variable data. Metaverse technology can achieve immersive, interactive, and personalized teaching, further stimulating students' learning interest and motivation, improving their participation and learning efficiency.

3.1.3 Resource Planning and Management

In terms of campus planning and management, metaverse digital twin technology can help schools better plan resources, including classroom utilization, equipment scheduling etc. to improve resource utilization.

3.1.4 Risk Management

Themetaverse digital twin technology can be used to simulate potential emergencies that may occur on campus, solving the problem of delayed feedback leading to the inability to provide timely decision support. Through virtualization, various data on campus can be more finely managed and controlled, and various security risks and abnormal situations on campus can be detected in a timely manner to assist schools in risk management and emergency preparedness.

3.2 Challenges

3.2.1 Technical Costs

The metaverse digital twin technology requiresa large amount of technological investment, including hardware equipment, software development, and investment. When the cost is too high, it will create huge resistance to the promotion of metaverse digital twin technology on campus.

3.2.2 Personnel Training

School staff need to adapt to and master the use of metaverse digital twin technology and the core concepts of the metaverse, which may require additional training and support, and some educational institutions may face the challenge of insufficient personnel training.

3.2.3 Privacy and Security Risks

The digital twin technology of the metaverse involves a large amount of data collection and processing, which may lead to privacy and security issues, especially when it comes to teacher-student information. Effective measures need to be taken to protect data security and privacy. There is still room for further improvement in virtual identity mapping, economic system construction, and immersive experiences.

3.2.4 Technical Standards and Operability

The metaverse digital twin campus is centeredaround data and models, and it is difficult to ensure multidimensional data consistency, data transmission stability, and data accuracy. The lack of unified technical standards and interoperability may make it difficult to integrate different systems, which may hinder the comprehensive application of metaverse digital twin technology in the campus.

4. Current Application of Metaverse Digital Twin Technology and its Prospects in Campus Application

4.1 Application

Metaverse twin technology, which simulates objects, systems or environments in the real world by creating virtual digital twins, has awide range of applications in multiple fields. In intelligent manufacturing, metaverse twin technology can be used to create virtual replicas of products or production lines for design validation, performance testing, and maintenance prediction. By simulating the production process, potential problems can be identified in advance, production efficiency can be

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optimized, and costs can be reduced; In agriculture,in the metaverse environment, the marking method and transformation method are used to highly restore scenesin virtual farms and conduct interactive performance tests. Reduce the research and development costsof crop no till planters and shorten the research and development cycle of crop no till planters [13]; In education, enhancing teaching effectiveness, innovating teaching methods, promoting the integration of industry and education, and creating multimodal digital twin IDs; Strengthen the cultivation of talents with digital concepts and technologies; In the tourism industry, the metaverse provides the ability to accurately replicate cultural and tourism resources from the real world into the virtual world, creating an open source, large-scale, and diverse database of cultural and tourism resources. The development model led by digital resources and combined with actual resources will gradually replace traditional large-scale real resource development [14]; In urban planning and management, urban managers can use metaverse twin technology to create digital twins of cities, simulating various scenarios of urban development and management, such as traffic flow analysis, public resource planning, and disaster emergency response; In healthcare, metaverse twin technology can be used in the medical field to design personalized treatment plans for patients, simulating disease development and treatment outcomes by creating virtual models of the patient's body. At the same time, it can also be used for surgical training and simulation to improve the operational skills of doctors; In energy management, metaverse twins can be used to simulate the operation of power grids, wind power generation, or solar power plants, conduct energy efficiency analysis and optimization control, in order to improve energy utilization efficiency; In entertainment games, metaverse twin technology can create highly realistic virtual environments and characters, providing users with a more immersive and interactive experience; In architecture and design, architects and designers can use metaverse twin technology to construct and test buildings and design schemes in virtual space, and evaluate the feasibility and aesthetics of the design before actual construction; In aerospace, metaverse twin technology can be used for the design and testing of aircraft and spacecraft, simulating various conditions during flight to ensure safety and performance. The development and application of metaverse twin technology are gradually changing the working methods of traditional industries, bringing opportunities for innovation and change to various industries. With the continuous advancement of technology, its application areas and influence are expected to further expand.

4.2 Outlook

Virtual real interaction technology is the core technology for immersive and interactive experiences in the metaverse, as well as a key entry point for the metaverse and digital twins. In order to provide users with a more immersive experience, virtual reality interaction technology has evolved from virtual reality (VR) technology that initially immerses itself in the virtual world, to augmented reality (AR) technology that overlays virtual information in the real world, and finally to mixed reality (MR) technology that integrates virtual and real worlds. As the virtual world and the real world switch more freely, interactivity gradually strengthens, and users can obtain a more realistic comprehensive experience [15].

The metaverse school integrates advanced technologies such as digital twins, the Internet of Things, artificial intelligence, augmented reality, and blockchain, allowing students, teachers, professionals, managers, and other users to engage in social, educational, and entertainment activities within the metaverse school through their virtual avatars. As an educational environment, metaverse schools can create new social spaces to meet the needs of different subjects, and it can support higher degrees of freedom in creation and sharing to achieve the cross temporal interaction and spatial collaboration. Meanwhile, the boundaries of user experience can be expanded by creating a stronger sense of immersion through virtualization. The metaverse school emphasizes the construction of an ideal virtual space for relevant personnel to learn, entertain, socialize, manage, and conduct scientific research, and provides a more diverse and colorful experience by expanding the types of activities, integrating virtual and real worlds.

5. Conclusions

This project innovatively introduces game engine technology into the metaverse digital twin system, combined with campus application scenarios, allowing us to see a new way of implementing digital twin technology in the metaverse and its new role in campus scenarios.

The digital twin campus of the metaverse can make intelligent decisions and optimize the campus operation process through simulation, analysis, and prediction of campus physical processes. As an educational environment, metaverse schools can create new social spaces to meet the needs of different subjects. It can support higher degrees of freedom in creation and sharing, to achieve cross temporal

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and spatial interaction and collaboration. Meanwhile, by creating a stronger sense of immersion through virtualization, the boundaries of user experience can be expanded. The metaverse school emphasizes the construction of an ideal virtual space for relevant personnel to learn, entertain, socialize, manage and conduct scientific research, and provides a more diverse and colorful experience by expanding the types of activities, integrating virtual and real worlds. The digital twin campus of the metaverse can significantly improve the digital service capabilities of the campus and enhance the level of information governance in the school. At the same time, the development process of this project has also made us realize that there are still some urgent problems to be solved in the application and promotion of metaverse digital twin technology, including the development of technical reserves related to metaverse digital twin systems and legal issues related to personal privacy that need to be discussed.

The concept of metaverse digital twins has important implications for intelligent manufacturing and digital transformation. To apply and promote digital twin technology on a large scale, it is necessary to fully consider issues such as safety, technology and cost to ensure that the metaverse digital twin technology can bring practical benefits to schools and provide better teaching and management tools.

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