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Digital Twin Technology Research and Development

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Abstract

With the continuous advancement of the digital transformation of the economy and society, digital twin technology has gradually become a hot technology of social concern. This paper briefly introduces the definition, origin and technical system of digital twin technology. On this basis, it introduces the implementation process of various key technologies, the collection and transmission of related data, and the modeling and simulation in digital space. The development of digital twin technology is inseparable from the development of big data, artificial intelligence, cloud computing, edge computing, and the Internet of Things. Fully illustrate the important role of digital twin technology in the construction of enterprises and industrial production, and briefly discuss the future development of digital twin technology.

Keywords

Digital twin; Industrial production; Intelligent manufacturing.

1. INTRODUCTION

Since 2019, the Chinese government has successively issued relevant documents to continuously promote the development of digital twin technology. Especially in 2021, the Chinese government will write digital twin technology into the "14th Five-Year Plan" as an important development direction for building a digital China.

From a policy perspective, digital twins have become an important starting point for promoting the process of economic and social digitalization at home and abroad. Major foreign developed countries formulate relevant policies at the national level, carry out cooperative research, promote the establishment of various organizational alliances, and accelerate the development of digital twin technology. The UK established a digital construction center and proposed a national digital twin plan in 2018, dedicated to building a national digital twin; the German Ministry of Economic Affairs and Energy has increased its control over the Industry 4.0 platform, and industry associations such as ZVEI and VDMA have established a national digital twin in 2020. The Industrial Digital Twins Association was established at the end of September. German policy focuses on the digitalization of manufacturing and urban management; the United States focuses on defense applications, such as military industry and large-scale equipment applications. The digital twin proposed by DARPA, a subsidiary of the US Department of Defense, in 2009 The U.S. military’s advancement of digital engineering aims to transform the previous linear, document-centered acquisition process into a dynamic, digital model-centered digital engineering ecosystem, enabling the U.S. military to complete the paradigm shift of doing things in a model-centered model. The development of the digital twin has been integrated into the system.

The importance of digital twins in China is no less than that of foreign countries. Local governments in my country have successively issued various relevant document outlines for digital twins, laid out the construction of digital twin cities in advance, and implemented

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supporting measures in full swing. The "Xiongan Planning Outline" proposed in the field of urban intelligent management "adhere to the simultaneous planning and construction of digital cities and real cities, moderately advance the layout of intelligent infrastructure, and build a world-leading digital city", "establish and improve the big data asset management system" , to build a world-leading digital city with deep learning capabilities" and other construction contents; the "Special Plan for Communication Infrastructure in Lingang New Area of China (Shanghai) Pilot Free Trade Zone (2020-2025)" was released, proposing to build a foundation based on the Yangtze River Delta, facing the An international communication hub and an international information port in the Asia-Pacific region and the world, in the Lingang New Area, the planning and construction of communication infrastructure such as 5G, optical fiber broadband, industrial Internet, Internet of Things, data centers and edge computing should be promoted in an overall manner. Twin City Pedestals.

This paper conducts an important investigation on the basic concepts and main technical systems of digital twins, and proposes key technical frameworks through the analysis of the survey results, and analyzes the development and prospects of digital twins in the direction of industrial production research.

2. DIGITAL TWIN CONCEPT

In layman's terms, digital twin is to build an identical entity in the virtual digital world through digital technology means, so as to achieve a deeper understanding, analysis and optimization of the physical entity. Professionally speaking, it is based on the integration and fusion of data and models. Through artificial intelligence, machine learning, deep neural network and other technologies, the data of physical entities is constructed in real time in digital space to accurately digitally map physical objects. Based on data integration Simulate, verify, predict, and control the whole life cycle process of physical entities with analysis and prediction, and finally form an optimized closed loop for intelligent decision-making.

Figure 1. Data Twin Digital Model

The concept of digital twin originated in the field of aerospace and military industry. It was first applied to the Apollo program in 1969, and it was required to provide a digital twin for the spacecraft of the program, so as to monitor its on-orbit working status at the ground control center and assist in handling emergencies. By 2003, the concept of digital twin was formally proposed by Professor Michael Grieves of the University of Michigan. After several years of conceptual evolution, in 2010, digital twin technology officially showed its application value in all walks of life. In the top-level science and technology planning document of the "Global Horizon" released by the US Air Force in 2013, Digital Thread and Digital Twin were regarded as "game-changing" subversive opportunities, so the US military Focusing on this opportunity, the digital twin-based F35 fighter jet has been realized digitally, and the digital twin is used to provide digital maintenance for the aircraft, reducing aircraft maintenance costs and use risks.

After the concept of digital twin was proposed, Siemens of Germany, Dassault of France, Parametric Technology Corporation of the United States, and General Electric of the United

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States followed up quickly and successively proposed their own digital twin concepts. Siemens closely follows the advantages of Industry 4.0 and intelligent manufacturing, and seamlessly integrates the real world and the virtual world through digital twins in the field of vehicles. Manufacturers can digitally design, simulate and test products through digital twins. Digital twins of processes and equipment. PTC American Parametric Technology Co., Ltd. is committed to realizing the digital real-time dynamic model of physical products, which can analyze product usage and status parameters in the real world in order to obtain functional requirements, so as to better provide value-added services to meet market needs. General Electric collects aero-engine data through big data, establishes a digital twin model, and conducts real-time monitoring and predictive maintenance of the engine.

Through the definition and understanding of digital twins at home and abroad, it can be said that digital twins are virtual mappings of the real world and digital models of real entities, which can more truly discover the characteristics and performance of physical products through simulation experiments on digital models, especially In the industrial field, the refined digital model mapped from the complete industrial process can find the optimization result of the production process to the greatest extent and in the shortest time, and enable the optimization of the production process. The digital twin can also realize the application value of mechanism description, abnormal diagnosis, risk prediction, decision assistance and so on.

3. DIGITAL TWIN KEY TECHNOLOGY SYSTEM

The digital twin technology system can be divided into four parts, the data base layer, the digital twin core entity, the analysis auxiliary layer, and the virtual interaction layer. The implementation of each layer is built on the basis of the previous layers, and is an extension and extension of the previous function implementation.

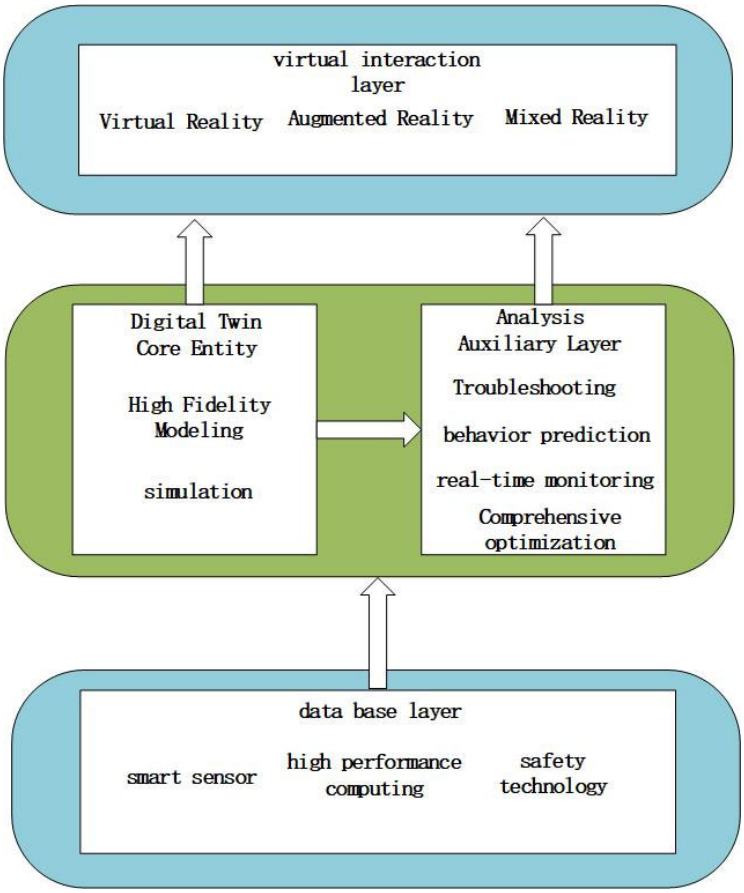

Figure 2. Digital Twin Technology System

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The data base layer is the cornerstone of the entire digital twin system. Data is the basis of the entire digital twin. The data of massive complex system operation contains important information for extracting and constructing system features. Compared with expert experience knowledge and systems, the real-time sensor information of the system is more accurate and can better reflect the system's characteristics. Implement physical characteristics [1], and achieve multi-dimensional and multi-level accurate monitoring of physical objects. The data base layer needs to collect multi-angle and cross-domain data from physical entities, upload it to the cloud through a high-speed data transmission network, model and simulate through high-performance computing, and complete analysis assistance.

In the digital twin system, the digital twin entity and the analysis auxiliary layer are the core of the whole system. After obtaining the data provided by the data base layer, the system is multi-physical and multi-scale high-fidelity modeling using data-driven methods and mathematical model-based methods [1]. In addition, data model fusion technology is needed to update, correct and optimize the model in real time to achieve dynamic evaluation [4]. Simulations are built on high-fidelity models that contain deterministic laws and complete mechanisms to reflect the characteristics and parameters of the physical world, verifying and validating the physical world.

The analytical assistant layer is the core function of digital twin technology. Based on the digital twin, the model and simulation of the physical entity are analyzed, predicted, diagnosed and trained, and the results are fed back to the physical entity, so as to realize fault diagnosis, behavior prediction, real-time monitoring, and comprehensive optimization.

The main purpose of the virtual interaction layer is to provide users with a good human-computer interaction environment, so that users can quickly master the digital twin system. The user's voice and body language are used to control access to the digital twin system and obtain information for analysis and decision-making.

4. DIGITAL TWIN KEY TECHNOLOGY

4.1. Smart Sensor

In order to establish a full-field and full-time perception system and realize multi-dimensional and multi-level accurate monitoring of physical test questions, sensors need more accurate and reliable measurement and perception technology. Therefore, the digital twin system puts forward higher requirements for sensor perception technology.

Since traditional sensors cannot meet the requirements of high precision, versatility and multi-dimensionality required by digital twins, it is necessary to adopt automatic zero calibration, drift compensation, overload protection of sensing units, data acquisition mode conversion, data storage, and data analysis. Smart sensors with the same capabilities, smart sensors can not only be used as data collection and upload ports, but also can spontaneously upload their own status information to build a digital twin of sensing nodes.

4.2. High Performance Computing

The realization of the functions of the digital twin system needs to rely on powerful computing power. Without powerful computing power, the important indicator of real-time performance cannot be achieved. The combination of optimized data structure and algorithm structure with distributed cloud computing platform is an important method to complete high performance computing. At the same time, the hardware performance of the computing platform, the transmission speed and transmission delay of the transmission network, the design of the algorithm structure with excellent performance, and the optimized data structure should also be considered.

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4.3. Safety Technology

Security technology refers to the security protection of data on the basis of meeting the timeliness and integrity of data collection and transmission to prevent third parties from tampering and stealing data. Current researches include digital twin models and security technologies for data management systems. Blockchain-based technologies can achieve tamper-proof, traceable, and traceable data resources.

4.4. High Fidelity Modeling and Simulation Technology

High-fidelity modeling and simulation is to map physical entities in virtual digital space into digital models that can be recognized by computers and networks, model problems in the physical world, and simulate the behavior of physical entities in real environments. As emerging technologies such as big data, artificial intelligence, Internet of Things, and cloud computing become more and more mature, modeling and simulation have entered a new stage of development, and are developing in the direction of digitization, networking, intelligence, and service. complete.

At present, the modeling languages for digital twins mainly include Modelica, AutomationML, UML, SYSML and XML, etc. A small number of models are developed using CAD modeling tools, and most of the development is based on special modeling tools such as FlexSim and Qfsm.

4.5. Virtual Interactive Technology

Through virtual reality, augmented reality, and mixed reality, the manufacturing, operation and maintenance of the system are more intuitive and more immersive. It allows users to see the physical world and combine virtual objects with the physical world, including a variety of Sensory modalities, such as vision, hearing, touch, somatosensory, and smell [7], enable real-time continuous human-computer interaction. At present, simulation collaborative analysis technology is mainly used for intelligent detection and evaluation of physical entities as an interface for visual and acoustic presentation, so as to guide and optimize complex production, testing, and operation and maintenance [3].

5. CONCLUSION

With the advent of the era of Industry 4.0 and the gradual development of emerging technologies such as artificial intelligence, big data, cloud computing, and the Internet of Things, digital twin technology has shown good development prospects in the field of intelligent manufacturing and equipment maintenance, whether for military or civilian use. All fields show great potential. From the beginning of the application of spacecraft, it has gradually developed into aircraft, robots, industrial production systems, new energy and smart cities, and more and more applications have been shown. However, because the software in the vertical field is controlled by others, most of the software is foreign commercial software, the professional level of independent software is not high, and there are certain constraints in technology and market, so it is necessary to vigorously promote the autonomy of modeling software. Whether it is sensor technology, simulation models, or high-performance computing, there is a certain gap with practical applications. It is necessary to explore while practicing, and constantly optimize and improve, so that digital twins can be integrated into practical applications more quickly.

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REFERENCES

[1] Liu Datong, Guo Kai, Wang Benkuan, Peng Yu:Summary and perspective survey on digital twin technology,Chinese Journal of Scientific Instrument,Vol. 39(2018),No.11,p.2-8.

[2] Tao F, Cheng J, Qi Q, et al:Digital twin-driven product design, manufacturing and service with big data,The International Journal of Advanced Manufacturing Technology, Vol.94(2018),No(9),p.3-11.

[3] Zhu Z, Liu C, Xu X:Visualisation of the digital twin data in manufacturing by using augmented reality, Procedia Cirp,Vol.81(2019),No. ,P.3-8.

[4] Nie R M, Zhou X Y, Xiao J,et al:Analysis and perspective on digital twin technology, Astronautical System Errgineering Technology,Vol.6(2022), No.1,p:1-6.

[5] Qi Q, Tao F.:Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison, Ieee Access, Vol.6(2018),No.,p.3-8.

[6] Rathore M M, Shah S A, Shukla D, et al:The role of ai, machine learning, and big data in digital twinning: A systematic literature review, challenges, and opportunities,IEEE Access, Vol.9(2021), No.,p.3-12.