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Research on the Application of Digital Twin in Smart Cities

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Abstract: With the development of technology, digital twin has played a non-negligible positive impact on the development of smart cities. From the mutually influential nature of digital twin and smart city, this paper analyzes the progress of digital twin technology in smart city applications through theory and case studies. The author examines three key cases: city brain, IoT cloud platform, and smart hub, to explore the application of digital twin technology in smart cities. In addition, the paper presents the potential problems of digital twin in smart cities, such as insufficient infrastructure, insufficient systematic data integration and few application scenarios. In future research, the author suggests that digital twin technology holds promise for enabling innovative applications in areas such as environmental protection, security, energy, healthcare, and tourism within smart cities.

Keywords: digital twin, smart city, urban management, Internet of things

1. Introduction

In recent years, the rise of urban overpopulation and ecological degradation has led to the emergence of "urban disease." As a solution, the construction of smart cities has gained traction. Leveraging advanced technologies, smart cities aim to optimize resource allocation, enhance productivity, and generate maximum value. The advent of the Internet and big data has opened up new possibilities for smart cities, enabling the mapping of real-world elements onto networked platforms and facilitating data mining. This integration of technology and urban infrastructure holds the potential to bring about greater efficiency and intelligence within cities. The interaction of two spaces is the fundamental condition for building smart cities, and the interaction technology of digital twin is one of the key technologies [1]. The digital twin is a widely used technology that can be useful in many fields such as manufacturing, energy, construction, healthcare, and agriculture. Digital twin can help companies and organizations to simulate and optimize their production and service processes to increase efficiency, improve quality, reduce risk, and boost innovation and competitiveness. The application of digital twin is promising and lays the foundation for the development of smart cities. However, more in-depth technological innovation and application development based on digital twin need to be continuously strengthened, so the ongoing research on digital twin is necessary and urgent [1]. This paper aims to investigate the influence of digital twin technology on the advancement of smart cities, employing theoretical analysis as the primary approach. The author will specifically concentrate on cases about the digital economy within the Chinese region. The paper will identify and examine existing challenges associated with digital twin implementation by analyzing these cases.

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Furthermore, the author will propose solutions and suggestions supported by sound theoretical frameworks, with the objective of facilitating the future development and application of smart cities. The study intends to provide valuable insights and guidance for effectively utilizing digital twin technology in the context of smart city initiatives.

2. Overview

2.1. The Development of Digital Twin

Digital twin is a technology that originated from the industrial manufacturing field and was initially used for simulation and optimization of product design and production processes [2]. As technology continues to advance, the application of digital twin technology has expanded to various domains, including energy, construction, healthcare, and agriculture. Digital twin involves the process of simulating, analyzing, and optimizing a physical object or system by synchronizing its data model with its actual operating state in real time through digital technology. In simple terms, digital twin is synchronizing the data model of a physical object or system with its real-time operational state. This synchronization enables the object or system to be simulated, analyzed, and optimized, leading to improvements in efficiency, cost reduction, enhanced quality, and risk reduction [3]. The development of digital twin has been made possible by the continuous advancement of technologies such as cloud computing, big data, and artificial intelligence, which provide digital twin with more powerful data processing and analysis capabilities, enabling them to be widely used in various fields. The development trend of the digital twin is toward more intelligence, automation and sustainability, which will bring more opportunities and challenges to all industries.

2.2. Relationship Between Smart Cities and Digital Twins

The development of smart cities and the digital twin are closely related. Smart city refers to the use of information technology and the Internet of Things and other technical means to provide comprehensive, efficient and intelligent management and services for cities, thereby improving city's operational efficiency, ecological environment and residents' quality of life. Indeed, the digital twin plays a significant role in the realization of a smart city. By harnessing digital technology, the digital twin enables real-time monitoring, simulation, and optimization of various city facilities, equipment, and resources. The digital twin serves as a virtual replica of the physical city, allowing decision-makers to gain insights into the city's operations, identify areas for improvement, and make data-driven decisions to enhance urban services and overall sustainability. Additionally, digital twin technology can support urban planners in their efforts to conduct urban planning and design. By creating a virtual representation of the city, urban planners can simulate various scenarios, test different design options, and assess the potential impact of their decisions [4].

3. Case Study of the Practical Application of Digital Twin in China

The comprehensive digitalization of cities by digital twin technology has realized intelligent management and services of cities, improving the operational efficiency of cities and the quality of life of residents. These successful cases show that digital twin technology has a wide application prospect and an important driving role in the construction of smart cities. New infrastructure, intelligent operation hubs, and smart application systems are the three horizontal layers of digital twin cities [4]. Although China started late with "smart city" and "new infrastructure" as the representative construction model, its burst of speed is unprecedented. Of the nearly 1,000 cities worldwide that have proposed smart development, approximately 500 are located in China, accounting for 48% of the global number. The successful implementation of digital twin technology has set a strong

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groundwork for future urban areas and infrastructure development in China [4]. Notably, cities like Hong Kong and Hangzhou have effectively utilized digital twin technology to pre-model, monitor, and optimize the construction and transportation within their urban environments in real time. This proactive approach has resulted in enhanced resource utilization and improved efficiency in urban transportation systems. By harnessing the power of digital twin technology, these cities have optimized their planning processes, made data-driven decisions, and achieved sustainable urban development. This section will delve into specific examples of digital twin applications in Chinese smart cities, providing a more comprehensive analysis of their impact and potential.

3.1. Building Cloud Asset-based networking Platform

The Hong Kong Housing Authority (HKHA) in Hong Kong, China, in response to high labor costs and land shortage, promotes prefabricated buildings in the production of public housing and outsources the production of prefabricated panels to Guangdong and contracts hundreds of small and medium-sized enterprise (SMEs) for the production, logistics and on-site assembly processes. However, HKHA faced various challenges in its construction processes, including high waste of time, space, and labor, as well as a lack of effective coordination and supervision. These issues were primarily attributed to the low adoption of information technology (IT) by the small and medium-sized enterprises (SMEs) involved and the fragmented nature of existing systems, which led to siloed information and inefficient workflows. As a consequence, construction cycles were often extended, budgets were exceeded, and wastage occurred. To address these issues, HKHA introduced a cloud-based asset-based integrated IoT platform for lean prefabricated buildings, which enables real-time monitoring and management of resources such as construction materials, equipment and workers, thereby improving the efficiency and quality of building construction. The system also enables intelligent data analysis and prediction to optimize and adjust the building construction process, thereby enabling lean construction and sustainability. This case exemplifies the significant potential and transformative impact of intelligent building management systems that leverage digital twin, IoT, and cloud computing technologies. These innovative solutions have wide-ranging applications and play a crucial role in the realm of prefabricated buildings. By embracing these technologies, construction enterprises can embark on a journey of digital transformation and intelligent upgrading, ultimately enhancing the efficiency and quality of building construction [5].

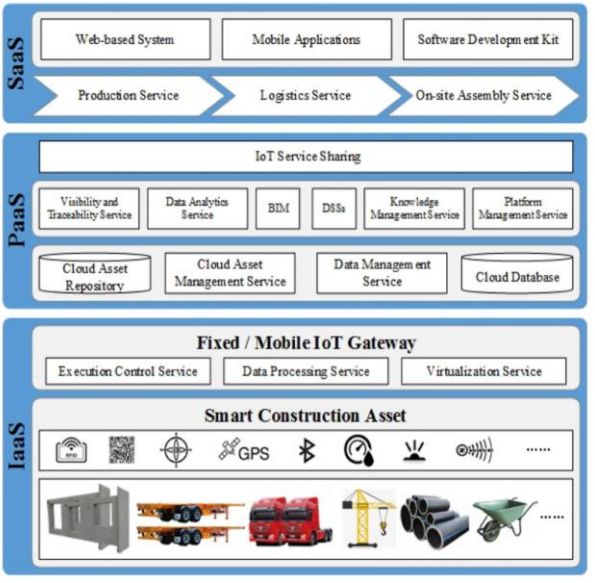

Figure 1: Technical framework of a cloud-based networking platform for prefabricated buildings [5].

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The platform is used for lean prefabricated buildings in smart cities, as shown in Figure 1, and consists of three main parts: a cloud platform, an IoT terminal and a mobile terminal. The cloud platform serves as the central component of the entire system, playing a crucial role in data storage, processing, and analysis. Moreover, the cloud platform offers advanced data analysis and prediction capabilities. The IoT terminal is used to collect data from resources such as building materials, equipment and workers, including a variety of sensor data such as temperature, humidity, pressure and vibration. Mobile terminals, on the other hand, are tools used to monitor and manage the building construction process in real time, allowing real-time monitoring and management of resources such as building materials, equipment and workers through mobile devices.

The utilization of mobile terminals in construction enterprises has the potential to advance cooperation and communication within the industry, leading to digital transformation and intelligent upgrades. In short, the underlying technology based on digital twin has a wide application prospect and an important role to play in the construction industry, making a positive contribution to the continuous construction and development of smart cities.

3.2. Hangzhou "City Brain" Case

The integration of digital twin, big data, artificial intelligence, cloud computing, and other technologies in the Hangzhou City Brain smart city platform has enabled real-time collection, processing, and analysis of diverse data within the city. This integration empowers city management and enhances public services through intelligent support.

The data sources of Hangzhou City Brain include urban traffic, public safety, environmental monitoring, social services and many other aspects. Among them, traffic data is the most important part, including traffic flow, congestion, bus location and other information. Through the analysis of traffic data, Hangzhou City Brain can realize the intelligent control of traffic signals, prediction and diversion of traffic congestion, and intelligent scheduling of buses, thus improving the efficiency and safety of urban traffic [6].

Hangzhou City Brain extends its capabilities beyond urban management and public services to include innovative applications in smart medical care and smart tourism. In the realm of smart medical care, Hangzhou City Brain proves invaluable by enabling various functionalities. These include intelligent deployment of medical resources, effectively allocating healthcare facilities to meet demand and optimizing service delivery. Additionally, the platform leverages data analysis and artificial intelligence to predict and prevent diseases, improving the efficiency and quality of medical services. Hangzhou City Brain also revolutionizes the tourism industry by offering intelligent features for an enhanced visitor experience. The platform provides intelligent recommendations for tourism resources, tailoring suggestions to individual preferences based on real-time and historical data. Furthermore, the system enables the real-time monitoring and management of tourists' behavior, ensuring crowd control and visitor safety, resulting in an overall improved quality and satisfaction in tourism services [6]. Hangzhou City Brain is a typical case of smart city construction in China, and through the application of digital twin and other technologies, it realizes real-time monitoring and management of all kinds of data in the city, providing intelligent support for city management and public services.

3.3. Hangzhou Yunxiao Platform South Station Hub Wisdom System

The Hangzhou Cloud Tsunami Platform South Station Hub Wisdom System is a digital twin wisdom transportation system, which is based on big data, artificial intelligence, cloud computing and other technologies, realizing real-time collection, processing and analysis of traffic data from Hangzhou South Station Hub, thus providing intelligent support for urban traffic management and public

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services. In the Hangzhou Cloud Tsunami Platform-South Station Hub Intelligent System, digital twin technology is widely used to realize the digital modeling and simulation of the South Station Hub [4].

First, through sensors and monitoring devices, the Cloud Tsunami Platform South Station Hub Smart System can collect real-time traffic data from the South Station Hub, including information on traffic flow, pedestrian flow, and vehicle location etc. These data are transmitted to the cloud, and through digital twin technology, a digital copy of the South Station Hub is established. Second, through the digital twin technology, the Cloud Tsunami Platform South Station Hub Intelligence System can simulate and predict the traffic situation of the South Station Hub. For example, the implementation of digital twin technology empowers an in-depth analysis of real-time traffic flow and pedestrian movement patterns. This enables the accurate prediction of potential traffic congestion in the bustling South Station Hub area. With this foresight, appropriate measures can be taken by the relevant staff to proactively manage the situation and implement diversion strategies to alleviate congestion and ensure smooth transportation operations. Finally, through the digital twin, the Cloud Tsunami Platform South Station Hub Wisdom System can optimize the traffic situation of the South Station Hub. For example, through intelligent control of traffic signals and real-time monitoring and management of parking spaces, the wisdom system can achieve relief of traffic congestion and improvement of traffic efficiency, while improving the efficiency and convenience of parking services.

4. Analysis of the Problems of Digital Twin in the Smart City

4.1. Insufficient Infrastructure Construction (IoT, 5G Bandwidth)

The application of digital twin in smart cities faces a number of problems, insufficient infrastructure is one of them, mainly in two aspects: Internet of Things and 5G bandwidth [1]. Insufficient construction of IoT and 5G bandwidth can affect the application of digital twin in smart cities.

The establishment of digital twin relies on sufficient data, and IoT is an important mean of data collection. Inadequate IoT construction can limit data collection, which in turn affects the application of the digital twin. In addition, the digital twin needs to transfer the collected data to the cloud server for processing and analysis, where 5G bandwidth plays an important role. If 5G bandwidth construction is insufficient, data transmission will be limited, which in turn will affect the use of the digital twin. Therefore, enriching the IoT construction and 5G bandwidth construction is crucial to enhance the effectiveness of the digital twin. In addition, the digital twin involves a large amount of urban data, and if the IoT and 5G bandwidth construction are insufficient, data collection and transmission will have security problems and be easily hacked and stolen, thus affecting the security of smart city construction. Finally, the digital twin needs a large amount of data to build the city model, and if the data collection and transmission are not smooth, it will affect the accuracy of the city model, thus affecting the application effect of the digital twin.

To address these challenges, it is essential to prioritize the strengthening of IoT infrastructure and the development of robust 5G networks. This will enhance the efficiency, security, and accuracy of data collection and transmission, thereby facilitating the wider implementation of digital twin technology in smart city contexts.

4.2. Insufficient Systematic Data Integration

Insufficient systematic data integration will affect the overall application performance of the digital twin in smart cities. The digital twin relies on the integration of data from various departments and systems, but inconsistencies in data sources, such as variations in formats and data quality, can hinder the performance of the digital twin. In addition, digital twin needs to integrate a large amount of city

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data to build city models, and missing or incomplete data will directly affect the precision and accuracy of city models. At the same time, digital twin needs to process and analyze the integrated data to extract useful information and knowledge, but if the data processing and analysis are not sufficient, it will affect the data accuracy of the digital twin output results. Finally, the digital twin needs to share and communicate the integrated data to relevant departments and personnel, but if the data is not shared and communicated well, it will affect the effectiveness and real-time of the construction of smart cities [7].

In order to solve these problems, it is necessary to strengthen the ability of data integration and sharing, and improve the efficiency and accuracy of data processing and analysis, so as to better promote the application of digital twin in smart cities.

4.3. Few Application Scenarios

There are relatively few application scenarios of digital twin in smart cities, and in Hangzhou smart city, for example, there are only 48 application scenarios [8]. Insufficient and inadequate application scenarios can indeed hinder the development and utilization of digital twin technology. When application scenarios are not detailed enough, it becomes challenging to analyze and optimize the intricate aspects of a city comprehensively. Lack of practicality in the application scenarios can limit their relevance to addressing the actual needs and challenges of a city. Moreover, when the application scenarios are not widespread enough, their benefits and potential impact may not reach all areas and departments of the city, resulting in limited adoption and slower progress.

To overcome these limitations and accelerate the development of digital twin technology, it is essential to focus on enhancing the breadth and depth of application scenarios. Detailed scenarios should be designed to enable in-depth analysis and optimization of various aspects of the city, addressing specific challenges and requirements. Practicality should be a key consideration, ensuring that the application scenarios align with the real-world needs of the city, taking into account factors such as resource availability, operational feasibility, and scalability.

5. Discussion

The digital twin has many more development applications that can be explored in the construction of smart cities. For example, in the field of environmental protection, digital twin technology can be used to improve urban environmental protection and sustainable development by simulating urban environmental pollution, optimizing environmental monitoring and predicting environmental changes. In the security field, the security level and emergency response capability of cities can be improved by simulating urban security events, adjusting placement layout, and predicting security risks. In the field of energy, through simulating urban energy consumption, optimizing energy supply and predicting energy demand to improve urban energy utilization. In healthcare, we simulate urban medical resources and predict disease epidemics to strengthen the level of urban healthcare and health management capabilities. In tourism, people simulate the tourism resources of the city, increase the multimodality of tourism services, and predict the tourism demand to improve the tourism level and cultural communication power of the city, as well as increase the economic income of the city.

6. Conclusion

The application of digital twin technology in smart cities is being developed and applied continuously. However, there are still some deficiencies in the current infrastructure, while data integration is not systematic enough and urban multimodal application scenarios are still being innovated and explored, resulting in very few truly realized digital twin smart cities. However, for the digital twin smart cities that are currently under construction, they have brought many benefits. This paper has some

limitations and is still not comprehensive enough for the field and scope of the cases. The author will study the development and impact of digital twin in smart cities from various countries and segments in more depth in subsequent studies. However, The author asserts that with ongoing technological research and development, the innovation and advancement of hardware devices, guidance from national policies, and enterprise implementation, the development of smart cities based on digital twin technology will experience exponential growth. As a result, an increasing number of urban applications leveraging digital twin technology will emerge. The author firmly believes that digital twin technology will serve as a fundamental building block for the Industry 4.0 revolution, making remarkable contributions to global development and progress.

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References

[1] *LI C, Liu J W, Wang L, Chen Y F. Digital twin in the application of intelligent city [J]. China Inspection and Testing, 2022,30(04):42-46. DOI:10.16428/j.cnki.cn10-1469/tb.2022.04.012.*

[2] *Lim K Y H, Zheng P, Chen C H, et al. A digital twin-enhanced system for engineering product family design and optimization[J]. Journal of Manufacturing Systems, 2020, 57: 82-93.*

[3] *El Saddik A. Digital twins: The convergence of multimedia technologies[J]. IEEE multimedia, 2018, 25(2): 87-92.*

[4] *Zhang Z L. Digital twins help the new infrastructure of future smart cities [J]. Information Construction,2021(09):30-32.*

[5] *Xu G, Li M, Chen C H, et al. Cloud asset-enabled integrated IoT platform for lean prefabricated construction[J]. Automation in Construction, 2018, 93: 123-134.*

[6] *Ben Q S, Peng X B. Artificial intelligence application embedded in government governance: Practice, mechanism and risk architecture: A case study of Hangzhou City Brain [J]. Journal of Gansu Administration College,2020(03):29-42+125.*

[7] *Mohammadi N, Taylor J. Knowledge discovery in smart city digital twins[J]. 2020.*

[8] *Yu J X, Fan L. Digital technology enabling social governance and its limits: A case study of Hangzhou's urban brain [J]. Comparison of Economic and Social Systems,2022(01):117-126.*