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Application of Digital Twin Technology in the Operation and Management of Water Diversion Project

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Abstract: *This paper analyzes the current situation of the operation and management of water diversion projects, combines digital twin technology, and preliminarily explores and forms a theoretical system for the application of digital twin technology in the operation of water diversion projects such as panoramic monitoring and unified water quantity scheduling management, and introduces the application of the above theoretical system in the operation and management of a water diversion project.*

Keywords: *water diversion project; digital twin technology; operation management; apply*

1. Introduction

With the development of technologies such as the Internet of Things, big data, 5G, digital twins and the mature application of hardware such as drones, how to make full use of new technologies and promote the digitalization and intelligence level of the operation and management of water diversion projects has become a hot spot in the current research on informatization of water diversion projects. As an effective way to realize real-time interaction and integration of physical and virtual world data, digital twin has received widespread attention and attention. With the help of digital twin technology, the digital twin and the operation and management of water diversion projects are analyzed theoretically, and a digital twin system for the operation and management of water diversion projects is constructed, which can enhance the comprehensive information perception ability, in-depth analysis ability, scientific decision-making ability and accurate execution ability of water diversion project, and greatly improve the intelligent operation and management level of water diversion project.

2. Status quo of operation and management of water diversion projects

The operation and management of water diversion projects involves many business fields, and the work content is relatively complex, including engineering operation monitoring, engineering inspection, engineering safety monitoring, water quantity scheduling management, facility and equipment operation and maintenance, etc., and all work has a strong system and comprehensiveness. During the "Thirteenth Five-Year Plan" period, the construction of major water diversion projects was comprehensively accelerated, the scope of water conservancy informatization was expanded, the application of related businesses was improved, and the informatization and intelligence level of water diversion projects were significantly improved. However, compared with the overall requirements of the national informatization development strategy and the needs of water conservancy reform and development, there are still some gaps and deficiencies in the current level of informatization and intelligence in the operation and management of water diversion projects, which are mainly manifested in the following aspects. First, due to problems such as environment, transportation, network, and capital, the automatic collection facilities for basic data of water diversion projects are not perfect, and the collection of some basic data still needs to rely on manual operations. Second, there is a serious imbalance of data resources in the relevant departments of the water diversion project, and there are a large number of information islands in the data of various business fields, which cannot make full use of big data, artificial intelligence and other technologies for data integration, analysis and optimization, and auxiliary decision-making.

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3. Theoretical analysis of the integration of digital twin and water diversion project operation and management

3.1 Digital twin

The concept of digital twin originated from the idea of "virtual digital representation equivalent to physical products" proposed by Professor Michael Griff of the University of Michigan in a product lifecycle management course in 2003 [1-2]. In 2012, the National Aeronautics and Space Administration (NASA) officially gave a clear definition of digital twin: digital twin is to make full use of physical models, sensor updates, operation history and other data, integrate multi-disciplinary, multi-physical quantity, multi-scale, multi-probability simulation process, complete the mapping of physical entities in the virtual information space, so as to reflect the full life cycle process of the corresponding physical equipment [3]. Specifically, various sensors are deployed to physical entities, and virtual models that map with physical entities, interact in real time, and collaborate efficiently with physical entities are built in information space by sensing the operating state of the physical world. This model can reflect the geometric parameters, physical properties, operation laws, etc. of the physical entity, the model has the functions of evaluation, optimization, prediction, etc., and can provide intelligent operation, accurate control and reliable operation and maintenance services based on physical entities and virtual models [4-5].

3.2 Integration analysis of digital twin and water diversion project operation management

Aiming at the operation monitoring business of water diversion project, using digital twin theory, based on GIS + BIM technology, integrating oblique photography model, BIM model, vector, terrain and other multi-source data, the physical entity of water diversion project is depicted in the information space, and the corresponding virtual model of water diversion project is constructed, and the virtual model and physical entity have accurate mapping relationship in terms of spatial location, geometry, physics, behavior, planning, etc. And the virtual model and the physical entity can realize real-time interaction of data through the service, so as to realize the visual panoramic monitoring of the operation and management process of the water diversion project. Aiming at the unified scheduling and management of water quantity in water diversion projects, a two-dimensional integrated simulation and simulation platform is established to realize the simulation of water quantity scheduling scheme and relevant elements of real-time scheduling process, and effectively improve the scientific and refined level of water quantity scheduling decision-making. Through the above analysis, it can be seen that the digital twin has built a bridge for the interaction and integration of physical entities and virtual models in time, and the digital twin system of water diversion engineering has been built with the help of digital twin technology, which has promoted the integration, exchange and sharing of multi-source heterogeneous data, which can realize real-time interaction and iterative optimization of the physical space and information space of water diversion engineering, and enhance the comprehensive perception, in-depth analysis ability, scientific decision-making ability and accurate execution ability of water diversion engineering information on a global scale.

4. Research on the application of digital twin technology in the operation and management of water conservancy projects

4.1 Application Analysis

With the continuous development of communication technology, big data, cloud computing, Internet of Things, etc. have become a very important innovation and growth point in the IT field, and combined with machine learning and deep learning algorithms to complete modern digital twin technology[6]. Digital twin technology has become an emerging research hotspot in the field of intelligent manufacturing and the intelligent operation and maintenance of complex systems. The operation and management of water conservancy projects not only involves business steps such as monitoring, early warning, scheduling, and maintenance, but also includes resource planning such as collection and storage. On this basis, a water conservancy data center is established to complete the collection, storage, exchange, update and sharing of water conservancy data throughout the life cycle. In this complex series of steps, the use of digital twin technology can help fully manage the water project and provide greater technical support. At present, with the rapid development of information technology, automation technology and communication technology, the shortage of information sources, poor data integration ability, low development and utilization efficiency and other shortcomings in water conservancy information projects are gradually optimized, and the dynamic management of water conservancy project operation is completed by constructing water

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conservancy data models, which lays a foundation for the spatial data and information interaction and integration of water conservancy projects.

4.2 Operating Mechanism

The digital twin of water conservancy engineering integrates advanced perception, computing, communication and control technologies, and realizes the dynamic connection and real-time interaction between physical space and information space by describing and modeling physical entities from geometry, physics, behavior, rules and other aspects in information space, and then realizes closed-loop management based on automatic data flow state perception, real-time analysis, scientific decision-making and accurate execution.

1) Unit-level hydraulic engineering digital twin system

Each unit-level hydraulic engineering digital twin system can perform state perception and computational analysis of the corresponding monitoring object and environment

The interactive integration of the physical world and the information world of water conservancy engineering is the smallest unit of the digital twin system of water conservancy engineering with perceptible, calculable, interactive, extensible and self-decision-making functions. Using advanced information technology, through real-time data collection, integration and monitoring, the physical entities of water conservancy engineering such as gate opening and closing machines, hydro generator sets, water transmission tunnels, drainage ditches, river channels, rain conditions, and water conditions are reconstructed in all elements from the aspects of geometry, state, behavior, and change in the information space, that is, the corresponding digital twin of water conservancy engineering is established to dynamically track the operating status and change trend of the physical space of water conservancy engineering (such as water level changes, voltage distribution equipment working status, etc.). Taking the digital twin system of the water conservancy engineering of the gate opening and closing machine as an example, through the perception module, all kinds of information about the gate opening and closing machine are collected, including the shape of the gate opening and closing machine, the opening and closing force, the traction force or the pressure applied by the gate opening or lowering (closing), the opening and closing stroke and opening and closing speed, the dynamic status of the opening and closing machine, the spatial scale, the gate vibration, etc., and the geometric model, physical model, behavior model, etc. of the gate opening and closing machine are established after data processing. In the process of gate operation, the gate opening and closing machine can be monitored and controlled in real time. During the change of the gate, if the gate movement model shows a large jump or disorder in the height of the gate jump, able to actively cut off the power supply, and analyze its reasons to feedback to the staff; When the vibration of the gate is detected at the current opening height, a control command can be sent to the gate opening and closing machine, the opening height can be adjusted appropriately, and the adjusted state will be reflected in the virtual model in real time through the perception module, and after repeated iteration, avoid the location where the vibration occurs; When abnormal phenomena occur, the fault location can be accurately located, the cause of the fault can be analyzed, and corresponding solutions can be formulated with the help of data mining methods such as support vector machine and dynamic Bayesian as well as knowledge base and experience database, so as to improve the ability of safe operation of the gate opening and closing machine.

2) System-level digital twin system for hydraulic engineering

The system-level water conservancy engineering digital twin system is for a single water conservancy project, based on the state perception, information interaction and real-time analysis of all unit-level water conservancy engineering digital twin systems, which improves the organization and decision-making ability of water conservancy engineering and realizes the optimization of overall resource allocation. With the help of fieldbus, Ethernet, wireless and other network technologies, the interconnection, interconnection and interoperability of multiple unit-level digital twin systems of water conservancy projects are realized, as well as the automatic flow of data between various functional modules in the entire water conservancy project, which further improves the breadth, depth and accuracy of the optimal allocation of water conservancy resources. System-level water conservancy engineering digital twin system fully considers the information provided by each unit-level water conservancy engineering digital twin system and the relationship between them, and performs unified scheduling of each module, thereby improving the collaboration efficiency between each unit-level water conservancy engineering digital twin system, ensuring the safe operation of water conservancy projects In the process of operation and application of the gate, the water digital twin system calculates the safe flow that can be

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discharged at the beginning of the flow by monitoring the upstream and downstream water levels, combined with the "safe water level under the gate at the beginning of the flow-flow relationship curve" in the knowledge base. After the gate is opened, if the water digital twin system detects that there are concentrated water flow, reflux, vortex and other adverse flow states in the water flow through the gate, the information will be fed back to the system-level water conservancy engineering digital twin system in real time, and the system-level water conservancy engineering digital twin system will schedule the gate opening and closing machine system, and appropriately adjust the gate opening height to eliminate abnormal phenomena.

3) SoS-class hydraulic engineering digital twin system

SoS-level water conservancy engineering digital twin system is for a certain river basin, composed of multiple system-level hydraulic engineering digital twin systems in the river basin, through the construction of an intelligent service platform, it can carry out unified monitoring, real-time analysis and centralized control of the working status of the system-level water conservancy engineering digital twin system, and has the ability of distributed computing and big data analysis of multi-source heterogeneous data, and collaboratively optimizes multiple components to achieve comprehensive perception, in-depth analysis, scientific decision-making and accurate execution of information within the global scope of the basin. In the joint flood control and dispatch of reservoir groups, the reservoir group composed of multiple reservoir cascades contains complex and diverse hydrological information, while the nonlinear relationship formed by different river basin sections, different water conservancy projects and hydraulic linkage between reservoirs requires diversified dispatch requirements, which greatly increases the difficulty of flood level management. Based on the SoS-level water conservancy engineering digital twin system, an intelligent service platform is constructed, and before flood control scheduling, comprehensively consider the real-time convergence forecast of cumulative net rainfall, the confluence forecast of inbound flow and other information, simulate the scheduling process in the information space, and grasp the status, behavior, task success rate, operation parameters, impact on upstream and downstream of each water conservancy project in the working environment, and problems not considered in the scheduling scheme. You can set the variable values in the virtual environment to simulate the operation of water conservancy projects in the river basin under different circumstances, and you can also simulate and verify the impact of different faults and unexpected situations on the execution integrity of the scheduling scheme, and finally generate the optimal resource allocation scheme and scheduling scheme that meet the scheduling requirements and constraints. In the process of scheduling, the operation of water conservancy projects in the river basin, the status of water conservancy facilities and equipment, and the water situation information in the river basin will be reflected in real time into the digital twin system of the water conservancy project, and the system will use data fusion, distributed computing, and big data analysis technology. Combined with real-time flood control reservoir capacity, reservoir immediate water level, rain and other information, the scheduling scheme is adjusted, and the adjustment result is applied to the physical entity in the water conservancy project in the form of machine instructions, so as to repeatedly iteratively optimize to realize the comprehensive utilization scheduling and resource allocation optimization of flood control, water supply, power generation, shipping, ecology and other reservoir groups, and maximize the utilization rate of water resources in the river basin.

5. Application of digital twin technology in the operation and management of water diversion project

5.1 Build a digital twin base based on GIS+BIM

Based on GIS + BIM technology[7], the digital twin base of water diversion project was constructed by integrating oblique photography model, BIM model, vector, terrain and other multi-source data, which realized the visual display of the panoramic view of the water diversion project and the building engineering information model of the important area of the project, and provided virtual model support for the integration of other system data . Based on the integration technology of digital twin base and Internet of Things, it integrates water diversion project overview information, water and rain monitoring information, flow monitoring information, water quality detection information, various alarm information, video surveillance information, project operation information, etc. At the same time, the deep integration of big data, AI and other technologies provides platform support for data visualization, simulation analysis, interaction and intelligent decision-making of water diversion projects.

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5.2 Water transfer unified dispatch management system

The water volume control system of the Shandong section of the first phase of the South-to-North Water Diversion Project uses the "digital twin" technology to establish a two-dimensional integrated simulation and simulation platform, and establishes a digital simulation body corresponding to the actual water diversion project in the computer. At the same time, combined with the characteristics of the project, the "synchronous control adaptive balance" scheduling control model was independently developed by using the principle of channel and pond storage balance, which realized the simulation of the water quantity scheduling scheme and the relevant elements of the real-time scheduling process, and effectively improved the scientific and refined level of water quantity scheduling decision-making .

6. Conclusion

Digital twin technology is currently in the process of rapid development, and more and more industry sectors are also using digital twin technology to improve the quality and efficiency of industry development. Water diversion project is an important infrastructure for the development of national economy, and this paper conducts theoretical research on the integration of the two in operation monitoring, unified water quantity scheduling and management and other business fields in view of the existing problems in the operation and management of water diversion project, combined with digital twin technology. The research results were applied in the operation and management of a water diversion project, which enhanced the scientificity and forward-looking operation and management of the water diversion project, and improved the informationization, visualization and intelligence level of the operation and management of the water diversion project.

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