Intelligent Construction Methods of Hydraulic Engineering Based on Digital Twins

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Abstract: Water conservancy and hydropower projects are characterized by large investment scales, extended construction cycles, high risks, strong concealment, and complex construction environments. The traditional construction model relying on two-dimensional drawings, manual experience-based management, and post-correction approaches can no longer meet the refined and intelligent construction requirements of the new era for water conservancy projects — namely, "greater safety, higher efficiency, greater economy, and enhanced environmental protection." Digital twin technology serves as a key enabler for advancing intelligent management in water conservancy construction. To this end, this study integrates digital twin technology with operational management to propose a digital twin-based intelligent construction methodology framework for water conservancy projects. Applying this framework to a seawall project, we developed a digital twin-based intelligent construction management platform for seawall engineering, achieving visualized, digitalized, and intelligent management across all project operations.
Keywords: hydraulic engineering; intelligent construction; digital twins; method application

1. Introduction

In the practice of intelligent construction for water conservancy and hydropower projects, the primary focus has been on hydropower projects such as Baihetan, Jinsha River, and Shuangjiangkou. Currently, intelligent construction of hydraulic engineering has gradually transitioned from the exploration stage to the systematization development stage, and has achieved good demonstration in some projects. However, there are still some challenges and limitations[1]. As a key technology for digital transformation and intelligent upgrading, digital twin technology has established relatively mature theoretical and technical frameworks in fields such as industrial product R&D and manufacturing[2], power systems[3], and smart cities[4], and is progressively advancing toward practical implementation.

This paper centers on project management, deeply integrating digital twin technology with business management to establish a digital twin-based intelligent construction methodology framework for water conservancy projects. Based on this theoretical framework, an application demonstration was conducted in seawall engineering, resulting in the development of a digital twin-based intelligent construction management platform for seawall projects. This platform achieves visualized, digitalized, and intelligent management by integrating various project management functions.

2. Framework for Intelligent Construction Methods of Water Conservancy Projects Based on Digital Twins

Digital twin technology serves as a key enabling technology for advancing intelligent management in water conservancy project construction. This paper references the five-dimensional digital twin model proposed by Tao Fei et al[5], integrates the requirements for digital twin-based water conservancy construction, and proposes a framework for intelligent construction of digital twin water conservancy projects based on the actual characteristics of water conservancy construction.

(1) The physical construction entities of water conservancy projects encompass the structures and components of the construction objects themselves, along with production factors related to these objects — such as personnel, machinery, materials, and the surrounding environment. They also include various information sensing devices, forming an all-weather, wide-coverage sensing network that extensively collects information on project conditions, hydrological conditions, rainfall, and other relevant data.

(2) The virtual construction model for water conservancy projects is a comprehensive collection of all virtual models corresponding to physical entities, including BIM models, GIS models, visualization models, and intelligent recognition models. The virtual space provides real-time feedback and control throughout the entire construction process by integrating continuously updated real-time construction data with accumulated historical data.

(3) Digital Empowerment Services constitute a suite of data-driven service system functionalities that provide systematic support and services for intelligent construction site management under the guidance of engineering construction digital

twin data.

(4) Twin data constitutes the core element of digital twins, encompassing data related to physical entities, virtual entities, digital empowerment service systems, and data generated through the integration of these three components.

(5) Connecting physical entities, virtual entities, and digitally empowered service systems into an organic whole enables the exchange and transmission of information, data, and knowledge across all components.

3. Digital Twin-Based Intelligent Construction Management Platform for Seawall Projects

3.1 Platform Architecture

The platform's technical architecture includes: (1) Building an integrated application system spanning IoT sensing, infrastructure, big data centers, and business applications, supported by the project's foundational network and resource management center. (2) Establishing two major supporting systems: information security and standards/specifications.

3.2 BIM+GIS Data Foundation Layer

Employing BIM+GIS technology, a three-dimensional model is synthesized using Digital Elevation Models (DEM) and Digital Orthophoto Maps (DOM) to establish a realistic 3D representation covering the entire seawall project.

3.3 Contract Management Module

Contract Management primarily enables centralized administration of various contract types within the assigned project section, including design contracts, construction contracts, equipment and material procurement contracts, technical consulting service contracts, and other contracts. It supports adding, deleting, and modifying contracts.

3.4 Progress Management Module

The Schedule Management Module primarily manages project progress through pre-execution, ongoing, and post-execution oversight across four key areas: schedule planning, progress feedback, comparative analysis, and progress reporting.

3.5 Quality Management Module

The Quality Management Module primarily enables dynamic real-time control of defect rectification and quality issues throughout the entire construction process at the granularity level of individual unit projects. It facilitates intelligent visualization and analysis of quality data, as well as smart management of testing and inspection information.

3.6 Safety Management Module

Establish a video surveillance system for the construction site to monitor critical work areas in real time. This system enables comprehensive, round-the-clock, and full-process safety oversight of the construction site, preventing and reducing various safety incidents.

4. Conclusions

This paper deeply integrates digital twin technology with business management to establish a digital twin-based intelligent construction methodology framework for water conservancy projects. Based on this framework, an application demonstration was conducted in a seawall project, developing a digital twin-based intelligent construction management platform for seawall engineering, the level of intelligent project management has been significantly enhanced.

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