Discussion on the New Operation Management Mode of Hydraulic Engineering Based on the Digital Twin Technique

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Abstract: With the rapid social development, water conservancy develops an increasingly important role on improving people’s life. Meanwhile, proposal of the digital twin technique arouses the extensive attention of people. In this thesis, the author analyzes its existing problems according to development situations of hydraulic engineering operation management and proposes an idea to apply the digital twin technique to hydraulic engineering operation management, hoping to realize intelligent hydraulic engineering operation, accurate control and reliable operation and maintenance, improve hydraulic engineering operation management level, and provide reference for further development of China’s hydraulic engineering.

1. Introduction

Hydraulic engineering operation management is an important measure to maintain stable development of society and economy in China. The “13th Five-year Plan” of National Water Conservancy Development defines to “place the deep reform in the outstanding position, lift the water safety to the national strategic height, and regard reinforcement of water conservancy management and further improvement on water governance and management ability as the important direction.” At present, China’s informatization keeps in the progress of rapid expansion. How to accelerate integration of water conservancy information and perfect integrated system of water conservancy informatization becomes a significant problem in today’s society. Proposal of the digital twin technique arouses people’s extensive attention. To combine the digital twin technique with hydraulic engineering operation management becomes an important means for us to develop “digital water conservancy” towards “wisdom water conservancy”.

2. Status and existing problems of hydraulic engineering operation management

In recent years, China takes various measures to reform the work in hydraulic engineering operation management. The management system in some areas is perfected, while management form of hydraulic engineering management units in most of areas is still lagging. And transformation of ideology is slow [1]. There is more behavior adjustment management in the management process. In addition, information exchange between departments is less insufficient, so that management efficiency is low. Hydraulic engineering has the scattered distribution and long lines for inspection. When managers inspect the hydraulic engineering site, the paper-medium mode is often used to record the inspection situations and it is typed in a computer by people. Manual entry has the big data size and it is easy to go wrong in the type-in process. Meanwhile, affected by a series of uncertain factors, including terrain environment, personnel quality, and weather conditions, it has the low efficiency, long periods of rechecking, and low accuracy of inspection data. Also, after entering into the information era, Internet of Things information technology has the rapid development, while hydraulic engineering monitoring technology generally is low and it is seriously uncoordinated with
social technological development, so that it seriously affects working quality and efficiency of hydraulic engineering operation management\cite{2}.

3. Necessity of applying the digital twin technique

3.1. Brief introduction of the digital twin technique

The concept of digital twin was proposed by Professor Grieves in full life cycle management course of University of Michigan in 2003 at the earliest. Then, the United States Department of Defense proposed to use the digital twin technique in health maintenance and safeguard of aerospace aircrafts at the earliest. At present, digital twin is mainly used for the producing department of aerospace structural parts and processing assembly workshops.

In a short, the digital twin technique deploys various sensors on the physical entities. By sensing the operational state of the physical world, the virtual model that is mutually mapped, mutually interacted and effectively collaborated with the physical entities in the cyberspace. This model can reveal the geometrical parameters, physical properties and operation rules of physical entities. The model is functioned with evaluation, optimization, prediction and assessment. Based on the physical entities and the virtual model, intelligent operation, accurate control and reliable operation and maintenance services can be provided\cite{3}.

3.2. Combination between the digital twin technique and hydraulic engineering

Combination between the digital twin technique and hydraulic engineering can get rid of the traditional manual management mode, associate with each party of hydraulic engineering construction, and realize information sharing, convenient communication and exchange. At the same time, using the digital twin technique can collect information relating to the hydraulic engineering construction, improve management efficiency and level, and guarantee hydraulic engineering construction quality.

Depending on the digital twin technique, information can be collected automatically to ensure that information collected by the system is real, reliable and accurate. Meanwhile, information in the hydraulic engineering construction process conducts systematic processing and treatment to provide scientific basis for decision-makers. In hydraulic engineering operation management, the digital twin technique is used to construct the uniform management information system, realize informationization operation of hydraulic engineering construction management, and enhance information processing efficiency. Using the digital twin technique can realize the transformation from tradition to modernity and from paper to digitalization, so as to realize resource sharing, convenient inquiry and rapid use and promote successful development of water conservancy modernization.

4. Application of the digital twin technique in hydraulic engineering operation management

4.1. Application features of the digital twin technique

Comprehensiveness: the digital twin technique conducts the full-element reconstruction for physical entities in the physical space, implements the comprehensive sensing and control for people, machines, objects, rules and processes, and realizes the optimal configuration of various resources.

Iterative optimization: the digital twin technique is used to construct the closed loop enabling system of automatic data circulation with “state sensing, real-time analysis, scientific decision-making and accurate execution”. Data are constantly accumulated and increased in a spiral way in this process, so as to generate more optimal data constantly.

Autonomy: the digital twin technique enables information space to deeply integrate with physical space and drives automatic data generation, automatic transportation, automatic analysis and automatic execution. Each sub-system organizes into groups and cooperates with each other to realize interconnection. Data and control parameters are stored in the system, thus the system has the ability of self-evolution and learning improvement and can greatly cope with the complicated environmental changes\cite{4}.
4.2. The system architecture of hydraulic engineering operation management based on the digital twin technique

The ultimate purpose of combination between the digital twin technique and hydraulic engineering operation management is to achieve the fine management of hydraulic engineering, improve resource configuration efficiency, and achieve the intelligent hydraulic engineering operation and its reliable operation and management. In order to achieve this goal, it is necessary to construct each subsystem based on the digital twin technique. The realization of each sub-system needs the automatic data circulation. In other words, various sensors and Internet of Things are used to transform the recessive data behind physical entities into the explicit data. Then, machine learning and data mining or other data processing analysis technologies are used to find out causality or correlation relationship in data. The explicit data can be transformed into more intuitive and comprehensible information. Under the constraint conditions, according to historical data and experience, the future is predicted to make an optimal decision. The final decision-making is transformed into the executive command in physical entities of hydraulic engineering and controls various devices, so as to guarantee reliable operation of physical entities and realize the rational scheduling of resources. In this thesis, from the perspective of data circulation, the hydraulic engineering operation management system based on the digital twin technique is divided into five layers, including physical layer, sensing layer, analytical layer, decision-making layer and executive layer[5].

1) Physical layer
The physical layer contains various physical entities and equipment devices. It exists objectively and it is the beginning of the entire closed-loop data system, the power source of automatic data circulation and the object of final decision-making execution.

2) Sensing layer
The sensing layer gains the data of physical entity state, uses sensors and Internet of Things to sense size, temperature and operation state of physical devices, and changes recessive data behind physical entities into visible and explicit data.

3) Analytical layer
The analytical layer conducts cognitive calculation, analysis and reasoning for explicit data, uses data mining and clustering analysis to make explicit data transparent and transforms it into information for intuitive comprehension.

4) Decision-making layer
The hydraulic engineering operation management system based on the digital twin technique will gain information from different sub-systems. According to historical data, realistic evaluation and future prediction, information is further analyzed and judged, so that it is transformed into the information in the knowledge layer. Then, an optimal decision is made under the constraint conditions.

5) Executive layer
The decision-making on the decision-making layer finally will act on the physical space. The executive layer transforms the decision-making into the command to be executed by the physical entities, which will accept various commands in the data form to complete the corresponding operation, so as to realize reliable operation and maintenance of physical devices and rational scheduling of resources.

Data circulation between five layers can be summarized in Figure 1.

4.3. The operation management system construction based on the digital twin technique

1) Automatic operation monitoring system
In order to improve the working efficiency, it is necessary to construct the automatic operation
monitoring system, which is used to realize automatic monitoring, involved in various telemetering instruments, data acquisition units, on-site communication networks, data communication system, and monitoring management system, so as to realize effective transportation of information and achieve efficiency, standardization and automation of maintenance\[^6\]. The automatic operation monitoring system detects the upstream and downstream water of gates, open-close state and opening of gates, as well as automatic acquisition and transportation of imaging information, aiming to control gate open-close of the monitoring center and supervise computational data. The limit range can be preset for these parameter values. When they exceed or repeat the limit, it is necessary to take the corresponding measures\[^7\].

2) Prognostics and health management (PHM) system

Prognostics and health management (PHM) means to use various sensors and data processing methods to evaluate health state of equipment and to predict equipment failure and residual life, so as to transform the traditional breakdown maintenance into pre-maintenance. PHM driven by digital twin is promoted by twin data to form the new mode of health equipment management, realize rapid capture of failure, accurately locate causes for failure, design and verify maintenance strategy reasonably based on synchronous mapping and real-time interaction of physical devices and virtual equipment, as well as accurate PHM services. This system is formed on the basis of the specific data model, which contains all kinds of data and information in hydraulic engineering construction and operation management and depends on the association between all kinds of data and information to construct the virtual model in the virtual space. This model is dynamically connected with realistic physical entities and can real information and states of hydraulic engineering in real time. For example, water flow changes, engineering scale and working conditions of equipment conduct the simulation. This virtual model can refer to the information, data and parameters collected to evaluate whether hydraulic engineering is safe. Also, this model can predict and find out possible problems in the hydraulic engineering construction.

3) Operation management system based on the digital twin technique

The hydraulic engineering operation needs to reinforce management. For this reason, a decision-making system that covers all directions can be established, including laws, regulations, systems, and policies in the water conservancy industry, previous solutions and treatment mode of similar problems, as well as comments and opinions of industrial experts. All operation management schemes and decision-making information are summarized and gathered to finally form a decision-making scheme system. The virtual model is constructed to simulate various schemes and finally form the ideal feasibility scheme through the scientific analysis. The hydraulic engineering operation management system is the effective dependence to do advanced hydraulic engineering management. Depending on this management system, the high-efficient hydraulic engineering management can be realized.

5. Countermeasures

The digital twin technique is used to the hydraulic engineering operation management. The government firstly should enlarge the R&D investment in relevant fields of the digital twin technique, mitigate punishments in tax revenues, establish a fund to encourage entrepreneurship for relevant technical fields, and help key enterprises. In addition, the government should positively guide social capital to the hydraulic engineering construction, regard the governmental investment as the guidance, further reinforce capital supporting, promote and enlarge total effective investments.

Led by relevant government departments, according to workers’ posts and responsible work tasks and their work ranges, it is necessary to do the specific training, thus they will accept the brand-new philosophy, positively enrich themselves, master some advanced technologies, and improve their technical level and professional quality. Meanwhile, it is essential to do qualification for hydraulic engineering management enterprises or personnel. Any management condition that does not conform to the practice should be eliminated to create conditions and make preparations or lean management of hydraulic engineering\[^8\].
All fundamental tasks and businesses of hydraulic engineering should be systemized, summarized and concluded in all directions. According to relevant work of the hydraulic engineering operation management, including water conservancy dispatching management, equipment management, project planning and manpower arrangement, lean management is realized to define the specific work quality indexes and performance standards of different departments and posts in the management work, so as to realize lean and standard operation of hydraulic engineering management and control management problems and shortcomings[9].

6. Conclusions
The digital twin technique constructs the virtual model that is dynamically connected with physical entities in the realistic world to dynamically reveal the real-time situations of each part in hydraulic engineering, combine Internet of Things, automatic control, machine learning, and clustering algorithm to help us to realize lean management of hydraulic engineering, and improve our working efficiency. We must reinforce the study on relevant fields, gradually reform the existing management system, realize the transformation from the traditional artificial management mode to digitalization, improve management level and ensure management quality.

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References
[1] Li Mingyuan, Hydraulic Engineering Management Operation Status and Coping Strategy[J], Shandong Water Conservancy, 2018(08): 56-57.
[2] Liu Fang, Existing Problems and Countermeasures of Flood Control and Drought Relief in the New Period[J], Heilongjiang Water Conservancy Technology, 2018, 46(05): 219-221.
[3] Akebail Mehmet, Discussion on Problems and Countermeasures of Hydraulic Engineering Operation Management[J], Jilin Water Conservancy, 2015(02): 52-53+ 62.
[4] Tao FEi, Liu Weiran, Liu Jianhua, Liu Xiaojun, Liu Qiang, Qu Ting, Hu Tianliang, Zhang Zhinan, Xiang Feng, Xu Wenjun, Wang Junqiang, Zhang Yingfeng, Liu Zhenyu, Li Hao, Chen Jiangfeng, Qi Qinglin, Zhang Meng, Zhang He, Sui Fangyuan, He Lirong, Yi Wangmin, and Chen Hui, Exploration on the Digital Twin and Application[J], Computer-Integrated Manufacturing System, 2018, 24(01): 1-18.
[5] Liu Wanlong, Comprehension on Reinforcing the Modernized Strategy of Hydraulic Engineering Management[J], Jushe, 2018(22): 195.
[6] Wang Hui, Luo Zhen, and Han Zhi, Brief Analysis on the Application of Automatic Monitoring System in Water Gate Operation Management[J], Technology Information, 2013(10): 406-407.
[7] Chen Dajun, Hydraulic Engineering Intelligence and Lean Management [J], Engineering Technology Study, 2018(01): 177-178.
[8] Qin Xiaozhu and Zhang Xingwang, the Application of Digital Twin Technique in Tangible Cultural Heritage Digitalization Construction [J], Information and Documentation Services, 2018(02): 103-111.
[9] Meng Jie, Real-time Monitoring and Dispatching System Study on Wanjiazhai Yellow River Diversion Project’s South Line Water Supply District[J], Water Conservancy Hydropower Technology, 2010, 41(07): 1-4+23.