Overview of Research Progress on Water Conservancy Big Data in China

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Abstract. Water conservancy big data refers to a technical means in the water conservancy industry that collects, stores, processes, and analyses massive amounts of data to reveal the laws of water resource utilization, water conservancy engineering operation, water disaster prevention and control, and provide scientific basis for water conservancy management and decision-making. This article reviews the research progress of water conservancy big data in China, analyzes the current application status, challenges, and future development trends of big data technology in the field of water conservancy. By reviewing existing literature, this paper explores how big data technology can assist in water conservancy informatization and intelligent management, as well as the future development prospects in areas such as further intelligence and digitization of water conservancy, data privacy and security, technology integration and innovation, talent cultivation and cooperation mechanisms, and regulatory and policy support.

Keywords: Water Conservancy Big Data; Water Resource Management; Data Security; Technological Innovation Informatization

1 Introduction

With the rapid development of digitization, informatization, and intelligence, big data has become a new driving force for high-quality social development and ecological civilization construction and has become an important force driving changes in various industries. China has always attached great importance to the important role of digitization, informatization, and intelligence in economic construction and social development, emphasizing the use of big data to promote the protection and improvement of people's livelihoods, deepening the application of digital technologies such as artificial intelligence, building a beautiful digital governance system in China, and building a green and intelligent digital ecological civilization. This highlights the important role of digital technology in ecological environment protection and points out the direction for accelerating the construction of a green and intelligent digital ecological civilization.

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Water conservancy, as an important component of national infrastructure, is related to the sustainable development of national economy, people's livelihood, and social economy. In the face of global climate change and population growth leading to water scarcity and frequent water disasters, it is particularly important to use big data technology to improve the intelligence level of water management. The application of big data technology is gradually changing the traditional mode of key links such as water resource management, flood control and disaster reduction, and water environment protection, providing strong technical support for achieving smart water conservancy. Water conservancy big data refers to a technical means in the water conservancy industry that collects, stores, processes, and analyses massive amounts of data to reveal the laws of water resource utilization, water conservancy engineering operation, water disaster prevention and control, and provide scientific basis for water conservancy management and decision-making. Water conservancy big data technology integrates advanced technologies such as the Internet of Things, cloud computing, and artificial intelligence, achieving comprehensive perception, efficient transmission, and intelligent analysis of water conservancy information. Through deep mining and analysis, it can provide more accurate and timely information support for decision-making. This article aims to summarize the current research status of water conservancy big data, explore its progress in data collection, processing, analysis, and application, and provide prospects for future development trends.

2 Current Status of Water Conservancy Big Data Research in China

2.1 Development History of Digital Water Conservancy

The development of water conservancy informatization in our country is basically consistent with the development process of computer information technology. By using modern information technology means to monitor, manage and operate water resources, the development process of digital water conservancy has generally gone through the following stages:

1) Early stage (before 2000): Due to the immaturity of information technology, traditional water management models still dominate, with manual or single instrument monitoring and management, and limited application scope of information technology.

2) Initial stage (2000-2010): With the development of information technology, digital water conservancy gradually emerged and was mainly applied in fields such as water resource monitoring, hydrological forecasting, and flood control scheduling. At the same time, large-scale water conservancy data centers and digital water conservancy application platforms have emerged.

3) Rapid development stage (2011-2019): Digital water conservancy has developed rapidly and is widely used in water resource scheduling, water supply allocation, and hydrological information updating.

4) Smart Water Conservancy Stage (2020 to present): The technology of digital water conservancy continues to upgrade, and the application of big data, artificial intelligence

and other fields is more extensive and in-depth, entering the stage of smart water conservancy development. The management scope of smart water conservancy is constantly expanding, including disaster monitoring in water related areas.

2.2 National Policy Support

Around 2000, during the 9th Five Year Plan period, China began to propose a plan for the informatization construction of basic water conservancy facilities under the "Golden Water Project"; As of the end of the 11th Five Year Plan in around 2010, China had basically built a water conservancy information network covering the national water conservancy system, formulated and improved a number of technical standards and norms for water conservancy information construction and management. During the period of the 12th Five Year Plan from 2011 to 2015, China's water conservancy information construction made significant progress, water conservancy information infrastructure basically supported the application of water conservancy business, water conservancy data resources basically met the application of their respective business fields, water conservancy information systems basically achieved full coverage of water conservancy business, water conservancy information protection environment basically ensured the process of water conservancy information, water conservancy information promoted and driven the transformation of traditional water conservancy to modern water conservancy, and the ability to serve and support water conservancy reform and development became stronger.

In 2016, the National Water Resources Ministry of China approved the 13th Five Year Plan for Water Conservancy Informatization, which requires innovation as an important driving force, deepening the integration of information technology and various water conservancy work, and actively researching the application of technologies such as big data, cloud computing, Internet of Things, and mobile internet in water work. In 2017, in order to comprehensively promote the implementation of the series of decisions and deployments of the Party Central Committee and the State Council on the development of big data, the Ministry of Water Resources issued the Guiding Opinions on Promoting the Development of Water Resources Big Data, marking a new stage in the development of water resources big data. In 2019, the Ministry of Water Resources officially issued the Guiding Opinions on Accelerating the Development of Smart Water Conservancy and the Overall Plan for Smart Water Conservancy. The country proposed the deployment of new infrastructure, and the academic community proposed concepts such as smart watersheds, smart water networks, water networking, and digital twins, marking the peak period of water conservancy big data development in China, which has aroused high attention and promotion of water conservancy big data construction in society. However, scientific research on it is still in its early stages.

2.3 The Main Research Areas

In recent years, China's water conservancy big data research has achieved fruitful results. In terms of data collection and integration, multiple water conservancy data cen-

ters and platforms have been established, achieving centralized management and sharing of various types of water conservancy data. In terms of data storage and management, distributed storage technology, cloud computing technology and other means have been adopted, effectively improving the efficiency and security of data storage. In terms of data analysis and mining, a series of data mining algorithms and models have been developed, providing strong support for water conservancy decision-making. In terms of data visualization and presentation, various visualization technologies and platform tools have been developed, making data presentation more intuitive and vivid.

1) Data collection and integration

The collection and integration of big data in water conservancy is the primary task of research. At present, research mainly focuses on the fusion of multi-source heterogeneous data, real-time data collection and transmission, and other aspects. Yunzhong Jiang et al. (2019)[1] believed that the collection means of water conservancy big data mainly fall into five categories: ground monitoring, satellite remote sensing, aerial remote sensing, Internet collection and model simulation (reanalysis). Through the establishment of unified data standards and interfaces, the interconnection of various water conservancy data is realized, providing a basis for subsequent data analysis and application. Wei Jiang et al. (2024)[2] gave an in-depth discussion on the application of remote sensing big data in water conservancy. The massive remote sensing data from high-resolution satellites provides strong technical support and guarantee for the development of water conservancy business, such as flood control and drought reduction, rational allocation of water resources, protection of water ecological environment, construction and management of water conservancy projects, and services. Jiming Chen (2023)[3] discussed the important role of IoT sensing technology in the water conservancy industry, which is one of the key foundational support technologies for achieving the development of smart water conservancy.

2) Data storage and management

The storage and management of water conservancy big data is another important research direction. With the continuous growth of data volume, how to efficiently and securely store and manage this data has become an urgent problem to be solved. Canyang Du et al. (2020)[4] pointed out that utilizing distributed storage technology, cloud computing technology, and other means can effectively improve the efficiency and security of data storage. Chao Zhou et al. (2021)[5] proposed a data management and exchange system for different categories and levels of countries, river basins, provinces, cities, and reservoirs. Based on the data management permissions of various water conservancy institutions, a bottom-up water conservancy data collection system was constructed to promote the aggregation of water conservancy big data resources. Chen Jiming et al. (2023)[3] believe that the transmission, storage, and analysis mining technology of the massive data information generated by water conservancy business work is the key technology faced by the development of smart water conservancy. The transmission, storage, and analysis processing of data are the core of achieving water conservancy automation, intelligence, and intelligent management.

3) Data analysis and mining

The analysis and mining of big data in water conservancy is the core content of research. Through in-depth analysis and mining of data, the patterns and trends hidden

behind the data can be revealed, providing support for water conservancy decision-making. Junfei Chen et al. (2017)[6] summarized and elaborated on the application of data mining in the field of water conservancy, including optimizing water resource allocation and water disaster warning. Jun Feng et al. (2021)[7] conducted a comprehensive investigation and in-depth analysis of the research status and development trends of knowledge graph construction in the field of water conservancy, hoping to promote the automation and intelligent processing of water conservancy data. Yongfa Xia et al. (2023)[8] discussed the important role of big data mining in water resource management. Through data mining and analysis, it is possible to better understand the status of water resources, improve water resource utilization efficiency, and promote the protection and sustainable use of water resources.

4) Data visualization and presentation

Data visualization and display are important aspects of water conservancy big data research. Through intuitive and vivid charts and images, the inherent patterns and characteristics of data can be more clearly displayed. With the continuous development of 3D visualization and digital twin technology, research on visualization of water conservancy big data is becoming increasingly mature. Beiqing Chen et al. (2016)[9] explored the design of water conservancy and hydropower engineering, and found that through three-dimensional intelligent collaborative design, the design period of the project can be greatly shortened, the availability of design results can be guaranteed, and the designers and construction parties at different stages of the project can work together efficiently to complete tasks. Yunzhong Jiang et al. (2019)[1] elaborated on the visualization technology of water conservancy big data. Water conservancy big data visualization can meet the needs of engineering construction, business management, and big data analysis in the water conservancy field. Hongwei Zhou et al. (2024)[10] used 3D simulation models, hydrological and hydrodynamic models, flood inundation models, etc. to achieve visual simulation of historical flood inundation situations, visually displaying the entire flood process under different working conditions, simulating the water level, flow rate of river channels and key gate pumps, and the evolution dynamics of coastal inundation ranges. They compared and analyzed the differences in flood inundation situations and evolution processes among different scheduling schemes.

3 Current Situation of Water Conservancy Big Data Engineering Construction

By the end of 2023, China had made comprehensive progress in the development of Digital Twin River Basins, Digital Twin Water Networks, and Digital Twin Engineering Constructions. The construction of a national first-level data foundation with a data volume reaching the petabyte (PB) level was completed.

The construction of an intelligent water conservancy business application system was accelerated, with the dynamic updating of electronic archives for over 210,000 water conservancy projects and the remote sensing image spot review of over 32,000 geographical features within the management scope of rivers and lakes.

The application of technologies such as Beidou, artificial intelligence, big data, remote sensing, and LiDAR continued to deepen, with the preliminary establishment of a high-performance computing cluster capable of 130 trillion double-precision floating-point operations.

As of 2024, China has established hundreds of new infrastructure facilities, including Digital Twin River Basins, Digital Twin Water Networks, and Digital Twin Engineering projects. A comprehensive monitoring and perception system integrating "Sky-Earth-Water-Engineering" has been basically formed, encompassing 23 remote sensing satellites, 2,500 unmanned aerial vehicles (UAVs), 15,000 video surveillance points, 155,000 ground-based hydrological stations for flood reporting, and tens of millions of engineering safety monitoring points.

Furthermore, the national water conservancy data foundation for 16 million water conservancy objects across 55 categories has been largely completed. Significant breakthroughs have been made in the research and application of over 40 independently controllable water conservancy professional models, including runoff generation and concentration calculations, multi-dimensional flood routing and inundation analysis, reservoir operation, river ice dynamics, upstream tidal impact and salinity analysis, among others. The large-scale artificial intelligence model for water conservancy has achieved operational application. These advancements have played a crucial role in major disaster prevention and mitigation efforts, such as the autumn floods in the Yellow River in 2021, drought relief and water supply ensurance in the Yangtze and Pearl River basins in 2022, flood prevention in the Haihe River basin in 2023, water supply guarantee for the Hangzhou Asian Games, and emergency response to dangers with Tuanzhouyuan in Hunan, Hama River in Jilin, and Laoha River in Inner Mongolia during 2024.

4 Challenges and Prospects of Water Conservancy Big Data Research

Although significant achievements have been made in water conservancy big data research, there are still some challenges to be faced. Firstly, data quality and data security issues still need to be further strengthened. Secondly, data standards and shared research still need to be further strengthened. Furthermore, the application of big data technology in the field of water conservancy still needs further deepening and innovation. Finally, interdisciplinary talent cultivation and cooperation still need to be strengthened to promote the in-depth development of water conservancy big data research.

1) Data quality and control: With the advancement of sensor technology, Internet of Things (IoT), and remote sensing technology, the accuracy of water conservancy data collection will be greatly improved. By using intelligent devices to monitor key parameters such as water level, water quality, and flow rate in real-time, combined with advanced algorithm verification, measurement errors can be effectively reduced, ensuring high accuracy of data. The future water conservancy big data system will pay more attention to the comprehensiveness and continuity of data. By optimizing the data collection network, covering a wider range of watersheds, water systems, and groundwater

resources, achieving full chain data tracking from water sources to users, ensuring data integrity, and providing more comprehensive information support for water resource management, flood control and disaster reduction, water quality protection, etc. By utilizing artificial intelligence and machine learning technologies, we can automatically identify and correct erroneous data, fill in missing values, and eliminate outliers, achieving intelligent and automated data cleaning and quality control. This not only greatly improves processing efficiency, but also continuously improves data quality, ensuring the reliability and accuracy of data analysis results.

2) Data standardization and interoperability: With the continuous improvement of industry standards and norms, the standardization level of water conservancy big data will significantly increase. A unified data format, interface protocol, and metadata management will promote efficient integration and sharing of data from different sources and formats, enhance data interoperability, and facilitate cross departmental and cross regional data collaborative analysis and application.

3) Data privacy and security: With the increase of data sharing, how to ensure the security of data and user privacy has become an urgent problem to be solved. Security and privacy protection. With the widespread application and sharing of big data in water conservancy, data security and privacy protection issues will receive increasing attention. In the future, it is necessary to strengthen the research and application of data security and privacy protection technologies to ensure the security and credibility of water conservancy big data.

4) Technology integration and innovation: The deep integration of emerging technologies such as artificial intelligence, the Internet of Things, and digital twins with big data in water conservancy will open more application scenarios. Technological innovation and application expansion; With the continuous progress and innovation of technology, the application of water conservancy big data will be more extensive and in-depth. On the one hand, new data collection and processing technologies will continue to emerge, improving the accuracy and real-time performance of data; On the other hand, big data analysis and mining technology will continue to advance, providing more accurate and intelligent decision support for water conservancy business.

5) Talent cultivation and cooperation mechanism: Interdisciplinary talent cultivation and the construction of cooperation mechanisms within and outside the industry are crucial for promoting the development of water conservancy big data.

6) Regulatory and policy support: Establish and improve relevant policy and regulatory systems to provide a favorable external environment for the application of water conservancy big data.

5 Conclusion and Outlook

Water conservancy big data research is a crucial direction in modern water conservancy, showcasing significant advancements but also facing challenges. To propel this field forward, it is essential to enhance data quality and security, foster deeper application and innovation of big data technologies, strengthen interdisciplinary collaboration,

and promote comprehensive research advancements. As a pivotal force in water conservancy modernization, water conservancy big data holds immense potential and requires consistent technological innovation, refined laws and regulations, and professional talent nurturing to ensure sustainable water resource management and protection. Looking ahead, it will play an increasingly significant role in safeguarding water security and promoting ecological civilization.

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