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Construction of a flood control and drainage decision-making command system—A case study of Suzhou Industrial Park

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Abstract. With the acceleration of urbanization, flood control and drainage management in cities are facing increasing challenges. As a nationally recognized model for effective flood control, Suzhou Industrial Park has experienced frequent extreme weather events in recent years, highlighting the urgent need for informatization in flood control and drainage management. This paper provides a detailed introduction to the design scheme of the flood control and drainage decision-making command information system for Suzhou Industrial Park, covering key aspects such as system requirement analysis, overall architecture, core technologies, and risk management. By integrating multi-source data, including meteorology, hydrology, waterlogging points, and the sewage pipeline network, the system establishes a comprehensive flood control and drainage decision-making platform featuring situational awareness, monitoring and early warning, and command and dispatching functions. The system aims to enhance the flood control and drainage capabilities of the park, ensure urban safety, and provide a reference for the informatization of flood management in other cities.

Keywords: Flood control and drainage, Information system, Suzhou Industrial Park, Monitoring and early warning

1. Introduction

In recent years, climate change has intensified, leading to an increasing frequency of extreme weather events. Flood disasters have become more frequent, severe, and widespread, exacerbating urban waterlogging issues and posing a serious threat to people's lives, property, and socio-economic development [1][2][3]. Meanwhile, as urbanization progresses, traditional flood control and drainage infrastructure struggles to meet the demands of modern urban development in terms of planning, design standards, technological capabilities, and operational management. This necessitates the adoption of modern information technology to advance the construction of a modernized urban flood control and drainage system [2][4]. In this context, flood control and drainage efforts should align with the stage of urban economic and social development, emphasizing the spatial attributes of urban water management systems [5].

A flood control and drainage decision-making command information system is an integrated platform that relies on data collection, communication transmission, and decision support as its core functions. The establishment of such a system is of great significance for improving flood control and drainage management. Scholars both domestically and internationally have conducted extensive research on the construction of flood control and drainage decision-making systems, achieving significant results. For example, Jian Zhang et al. [6] proposed a flood control command system for the Chengnanwei area of Kunshan, which utilizes water level monitoring data for enhanced decision-making. Lianjie Wang [7] developed a flood control and drainage hydraulic model based on the InfoWorks ICM model to evaluate flood control systems and support their planning and design. Building upon these prior studies, this research aims to construct a more comprehensive and efficient flood control and drainage decision-making command system, providing strong support for safeguarding lives, property, and sustainable socio-economic development.

2. Project background

Suzhou Industrial Park, known nationwide for its effective flood management—earning the reputation of a city that "does not turn into a sea after heavy rain"—has achieved a flood protection standard for events occurring once in a century. However, it still faces challenges brought by extreme weather conditions. The impact of Typhoon "In-Fa" in July 2021 and the torrential rains in October 2021 highlighted existing weaknesses in flood control and drainage management, particularly in command and dispatch, as well as monitoring and early warning systems. In response, the Suzhou Industrial Park Bureau of Ecology and Environment proposed the development of a flood control and drainage decision-making command information system to enhance the district's flood management capabilities through digitalization, ensuring urban safety.

To address the existing issues in flood control and drainage while aligning with the park's development goals and operational needs, it is imperative to leverage advanced technologies such as cloud computing, the Internet of Things (IoT), big data, and artificial intelligence. The goal is to establish a comprehensive flood control and drainage decision-making command system that integrates full-element visualization, command and dispatch, monitoring and early warning, flood management, and situational awareness, thereby significantly improving the park's flood management capabilities.

3. Overall system design

3.1. Requirement analysis

The primary goal of the Suzhou Industrial Park Flood Control and Drainage Decision-Making Command Information System is to resolve existing issues in flood management, including inadequate monitoring, delayed situational awareness, and traditional command and dispatch methods. The system aims to enhance the park's flood management capabilities, improving both efficiency and effectiveness. The specific business requirements are categorized as follows: Situational Awareness in Flood Management: The system should establish a unified flood information aggregation and display platform, offering an intuitive overview of the flood situation. It should present comprehensive, multidimensional flood control and drainage data. Command and Dispatch Requirements: The system should optimize flood response coordination through digital solutions such as audio and video conferencing and one-click emergency meetings. This will facilitate the efficient deployment of personnel, equipment, vehicles, and flood control materials. Monitoring and Perception Requirements: The system should develop a robust monitoring and perception framework to improve flood data collection, monitoring accuracy, and overall assessment capabilities.

Based on these requirements, the system is designed with the following six core functional modules:

(1) Comprehensive Flood Control and Drainage Visualization: Utilizing GIS mapping, the system will integrate meteorological data, hydrological conditions, waterlogging points, sewage pipeline networks, emergency incidents, personnel and material resources, and video surveillance. This will provide a real-time, comprehensive "flood control and drainage panorama."

(2) Urban Water Supply and Drainage Visualization: The system will incorporate monitoring data from Qingyuan Huayan Water Services, including water treatment plants, pumping stations, potable water pipelines, wastewater treatment plants, sewage pumping stations, and sewer networks. This will facilitate a visual representation of water supply, drainage, and water resource distribution.

(3) Integrated Water Environment Management Visualization: The system will connect with the Jinji Lake Water Environment Management System, integrating sluice and pump monitoring data along with video surveillance to display critical water quality monitoring information of key rivers and lakes.

(4) Flood Monitoring and Early Warning Management: The system will support real-time monitoring of meteorological conditions, water levels, flow rates, water quality, waterlogging points, and sewage pipeline networks. It will also offer functions for historical data retrieval, filtering, and exporting.

(5) Flood Management: The system will digitize various flood control operations, including contact management, emergency response planning, and routine flood control tasks.

(6) Mobile Flood Control Application: Built on the Government Affairs App and Grid Communication App, the mobile platform will provide functionalities such as flood situation visualization, personnel communication, audio and video calls, and flood disaster reporting.

3.2. Overall Architecture

The Suzhou Industrial Park Flood Control and Drainage Decision-Making Command Information System is designed around flood control and drainage operations, following the principles of "resource sharing, force integration, and method centralization." The system aims to address key shortcomings in flood management, such as insufficient monitoring, delayed situational awareness, and traditional command and dispatch methods. Its core objectives are:

"Risk Hazards Can Be Monitored" – The system aggregates and displays real-time data on various flood risk factors, enhancing informatization to enable timely monitoring and early warning of flood risks.

"Flood Situations Can Be Seen" – By fully integrating flood control and drainage data resources, the system provides a comprehensive and macroscopic view of the overall flood situation, ensuring seamless information sharing for leadership to quickly grasp the full picture.

"Personnel and Materials Can Be Commanded" – A flood command system will be established to vertically connect municipal flood control offices, district-level flood control offices, and street-level management, while also horizontally integrating emergency response teams, law enforcement, and other flood control units. This structure ensures a highly efficient, top-down and cross-sector command and dispatch system.

The system adheres to the principles of maximizing existing resources, service-oriented convenience, reusability, and security. It integrates with external systems such as the Municipal Meteorological Bureau, Municipal Water Affairs Bureau, Qingyuan Huayan Water Services, and the Environmental Protection System of Suzhou Industrial Park. Coupled with a comprehensive monitoring and sensing network, the system enables flood situation visualization, intelligent scheduling, and real-time monitoring and early warning. The overall architecture of the flood control and drainage decision-making command information system consists of five key layers:

Presentation Layer – Includes large display screens, PC interfaces, and mobile applications.

Application Layer – Leverages the park's flood control framework and integrates with external systems (e.g., the Municipal Meteorological Bureau, Municipal Water Affairs Bureau, and Environmental Protection System) to provide:

Comprehensive flood control visualization

Water supply and drainage visualization

Water environment management visualization

Monitoring and early warning management

Flood management functions

Mobile flood control applications

Application Support Layer – Includes video conferencing platforms, video management platforms, monitoring equipment management platforms, AI algorithm platforms, water resource data collection software, and an integrated portal system.

Infrastructure Layer – Covers networking, storage, security, large display screens, multimedia systems, and video conferencing facilities.

Perception System – Comprises meteorological and hydrological monitoring systems, waterlogging monitoring systems, sluice and pump monitoring systems, and video surveillance.

This architecture ensures a cohesive, intelligent, and highly efficient flood control and drainage system, strengthening Suzhou Industrial Park's ability to respond to extreme weather events while serving as a model for other urban flood management initiatives.

4. Key technologies implementation

4.1. Microservices architecture

The system adopts a microservices architecture based on the SpringCloud framework, designed to build applications around business domain components, enabling independent development, management, and scaling. The advantage of a microservices architecture lies in the fact that each service can be developed, deployed, and expanded independently, enhancing system flexibility and maintainability. By implementing a microservices architecture, the system enables the independent development and deployment of multiple functional modules, including comprehensive flood control and drainage visualization, urban water supply and drainage visualization, and integrated water environment management visualization.

4.2. Unified identity and access authentication

The unified identity and access authentication system is designed with a hierarchical structure, primarily divided into data layer, authentication channel layer, and authentication interface layer. It consists of multiple functional modules, with the identity authentication module and access management module being the most critical. The system implements unified identity authentication based on OIDC (OpenID Connect) to ensure security. The advantage of this design is that OIDC builds an identity layer on top of the OAuth2 protocol, supporting various types of clients (such as web applications, mobile terminals, and JavaScript client programs) while providing strict authentication mechanisms. By adopting a unified identity authentication mechanism, the system ensures strict access control for different user roles (such as flood control command unit members, flood control office staff, and frontline emergency personnel), preventing unauthorized access.

4.3. Load balancing service

The system implements load balancing based on Nginx, ensuring high concurrency response capabilities. The advantage of a load balancing service is that it distributes incoming requests across multiple operational units (such as web servers, FTP servers, etc.), thereby increasing system throughput and processing efficiency while enhancing network flexibility and availability.

4.4. Distributed file storage

The system leverages MinIO for distributed file storage, ensuring efficiency and reliability. The advantage of distributed file storage is that it distributes large amounts of data across multiple nodes, reducing the risk of data loss while providing redundancy and scalability. By employing distributed file storage technology, the system enables the efficient storage and management of large-scale unstructured data, including flood monitoring data and video surveillance data.

4.5. Centralized logging system

The system utilizes ELK (Elasticsearch, Logstash, Kibana) for centralized logging, ensuring maintainability and traceability. Centralized logging consolidates all system logs into a dedicated server, facilitating log management and analysis, thereby improving system maintainability and fault diagnosis efficiency. Through centralized logging, the system enables real-time monitoring of operational status, allowing timely detection and resolution of potential issues to ensure stable system operation.

5. Conclusion

The construction of the Suzhou Industrial Park Flood Control and Drainage Decision-Making Command Information System will bring significant economic and social benefits.

From an economic perspective, the system enhances flood control situational awareness through digitalization, enabling real-time monitoring and visualization of all flood control and drainage elements to ensure high efficiency and precision in flood management. Additionally, by deploying monitoring and sensing devices, the system strengthens the flood monitoring and early warning framework, improving flood perception methods, monitoring targets, and data accuracy to provide a solid data foundation for decision-making and command operations. Furthermore, by integrating emergency plans, decision-making deployment, real-time consultations, command and dispatch, and on-site tracking, the system establishes a visualized command and dispatch model, significantly accelerating response efficiency during flood emergencies and enhancing coordination and emergency response capabilities among flood control units.

From a social perspective, the system significantly enhances government service capabilities by optimizing flood control scientific management and operational efficiency through digitalization, improving the government's ability to handle emergencies. The real-time monitoring and early warning functions bolster urban flood control and drainage capacity, effectively preventing the severe consequences of urban waterlogging, which can disrupt public safety, daily life, and transportation systems. Additionally, by enabling timely risk detection and public assistance response, the system strengthens government-public relations, fosters social cohesion, and lays a solid foundation for a safer and more harmonious society.

In conclusion, the successful implementation of the Suzhou Industrial Park Flood Control and Drainage Decision-Making Command Information System not only enhances the park's flood control capabilities and ensures urban safety but also serves as a valuable reference for the informatization of flood control systems in other cities. The project demonstrates the crucial role of digital technologies in improving urban management and public services, making it highly applicable for broader adoption and promotion.

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