

Research and design of urban flood control and drainage dispatching system

Guibing Hou^{1, a}, Jiantao Lu^{1, b}, and Yuanyuan Li^{1, c *}

¹China Water Resources Pearl River Planning Surveying & Designing CO. LTD,
Guangzhou, China;

^a 355420256@qq.com, ^b jadylnlu@163.com, ^c 1034308156@qq.com

Abstract. In order to solve the problem of frequent flood disasters in urban areas, water conservancy models such as hydrological forecast, flood simulation and operation decision-making were studied and constructed for the waterway-region-urban flood control and drainage engineering facilities, and urban flood control and drainage operation system was designed with the model as the core. The overall structure of the system is "five horizontal and two vertical". The "five horizontal" bottom up are respectively the intelligent perception layer, cloud infrastructure layer, data layer, service layer and application layer, and the "two vertical" are respectively the security system and the standard specification system. On this basis, the function customization of the system is completed to achieve comprehensive display, early warning and forecast, flood simulation, risk assessment, project scheduling and intelligent decision-making functions.

Keywords: Flood control and drainage; Dispatching system; Urban areas; System design

1. Introduction

With the rapid economic and social development in China, urbanization is advancing rapidly, the original farmland has become urban areas, and the flood channels outside the city have become urban drainage ditches, causing local water systems to be disordered. In the context of global climate change, extreme weather occurs frequently, and heavy rain and flood disasters have become a normal phenomenon in cities and towns. Drastic human activities during urbanization change the underlying surface, the relationship between production and runoff and drainage in river basins have become the main causes of flood and flood disasters in urbanization areas [1].

In recent years, relying on the rapid development of information technology, China's flood control and drainage information construction has made great progress, and the development and application of water information collection and water management system in the industry has also achieved remarkable results in the continuous practice of hydrology, water power, reservoir dispatching and other aspects. A large number of studies have shown that the construction of a real-time flood control and drainage scheduling system integrating information mining, risk control, intelligent scheduling and decision-making services has become an effective way to improve flood monitoring, early warning and emergency management capabilities in highly urbanized areas.

2. Data and Methods

2.1 Data materials

In order to study and design urban flood control and drainage dispatching system, it is necessary to integrate spatial data such as watershed and regional land, traffic, water system, terrain and important facilities, and integrate basic information of water conservancy projects such as key reservoirs, sluices, pumping stations and embankments. Secondly, it is necessary to collect basic information such as water level, rainfall, discharge and flood disaster of important stations in the basin to provide basic data support for intelligent scheduling and early warning of projects. Finally, it is necessary to include the basic information of basin engineering, the real-time monitoring information of the water level outside the sluice pump, and the scheduling information of sluice

pump, etc., and integrate the scheduling rules of flood control and drainage facilities such as reservoirs, sluices and pumps in the region.

2.2 Construction of flood simulation model

According to the idea of "large-scale early warning and small-scale fine simulation", a watershed - regional flood simulation model is constructed. The large-scale hydrodynamics model was used to simulate the basin area, and the small-scale hydrodynamics coupling model was used to simulate the urban area. The hydrological model can be the plain hydrological model, Xin 'an River model, TOPMODEL and Huaibei model. The hydrodynamic model includes zero dimension storage, one dimension river network, two dimension river network and pipe network model. There are various ways of model coupling, which can be roughly divided into loose coupling and tight coupling according to the degree of tightness. Loose coupling requires human participation in setting information transfer between implementation models. Tight coupling requires secondary development to achieve model automation [2].

2.3 Multi-Source Data Fusion

A set of fusion rainfall data with high temporal spatial accuracy was developed by means of three data sources, namely satellite, radar and ground observation, to improve the spatio-temporal accuracy and accuracy of multi-source rainfall data [3]. Firstly, the collected radar and ground observation data are inspected and controlled. Secondly, on the basis of satellite and radar data, the measured data of ground observation stations are used for fusion correction by Cressman interpolation [4]. Cressman interpolation algorithm was proposed by Cressman et al in 1959. It adopts the stepwise correction method for optimal interpolation. The specific expression formula is as follows:

$$a' = a_0 + \Delta a_{ij} \quad (1)$$

$$\Delta a_{ij} = \frac{\sum_{k=1}^k (W_{ijk}^2 \Delta a_k)}{\sum_{k=1}^k W_{ijk}} \quad (2)$$

Where, a is any meteorological element (such as precipitation, wind, temperature, etc.); a_0 is the first guess of the variable a at the lattice point (i, j) ; a' is the setting value of the variable a at the grid point (i, j) ; Δa_k is the difference between the observed value at the observation point k and the first guess value; W_{ijk} is a weight factor with a range between 0.0 and 1.0; k is the number of stations within the radius of influence R .

2.4 Multi-model integration and invocation

Due to the implementation of this system being based on the invocation and coupling of multiple models, the flood control and drainage scheduling decision-making task can be decomposed into modules such as rainfall-runoff calculation, hydrodynamic process calculation, water resources engineering scheduling simulation, flood risk simulation, and optimization decision-making. Therefore, the entire system architecture adopts a plugin-based expansion model algorithm architecture. The essence of a plugin is to extend and enhance software functionality without modifying the program body. Once the interface standards of the plugin are established and solidified, subsequent functions can be easily modified or added, thus solving some operational inconveniences and achieving more stable and reliable software functionality expansion. This system can add new models suitable for research scenarios according to actual application needs, making the supplementation and application of the model library more flexible and improving the system's applicability.

To achieve interoperability among multiple models in a system, model composition techniques need to be utilized. The process of model composition includes the integration of control flows and the transfer of information flows. To realize the invocation and interoperability of multiple models, the following approach is adopted for relationship handling, as shown in Figure 1.

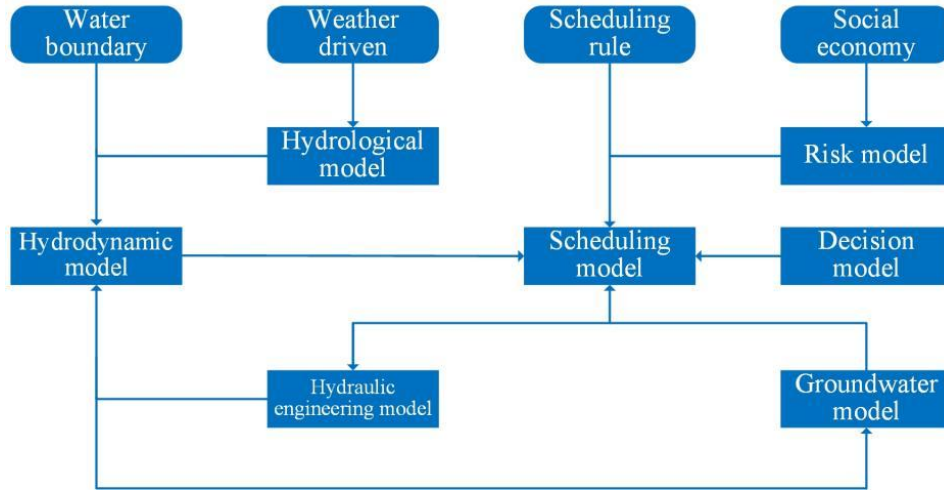


Figure 1. Invocation relationships among multiple models

3. System design and implementation

3.1 Technical Architecture

Based on the microservices architecture pattern [5], the urban flood control and drainage scheduling system is built using the Spring Cloud framework, forming a highly available, rapidly deployable, scalable, and easy-to-develop flood control and drainage scheduling application system. By adopting a web service-based technical architecture, it facilitates dynamic and cross-organizational resource collaboration and seamless automatic composition of decentralized and independent web services to meet user requirements [6-8].

The technical system consists of three layers: the support service layer, the business service layer, and the interface layer. The support service layer includes data services, security services, interface services, search engines, GIS engines, institutions and permissions, as well as basic support and forecast model services, water resources model services, and scheduling service model services, providing basic service support for the business service layer. The business service layer includes comprehensive display, early warning and forecasting, flood simulation, risk assessment, intelligent decision-making, and other business unit management modules, as well as data access for Webservice interfaces and data aggregation, supporting cross-platform invocation, thereby enhancing the system platform's scalability. The interface layer, based on the business services, presents a friendly and concise interface with HTML5 WEB and the mainstream REACT front-end framework for intuitive visualization.

3.2 Overall system framework

The urban flood control and drainage scheduling system aims to support the decision-making of watershed-region-urban flood control and drainage engineering facilities. Based on the existing cloud environment and considering the openness, compatibility, and scalability of the system, it relies on various data, maps, and functional services. It establishes a spatial information resource management and sharing system, combining with mainstream GIS technology. The overall architecture follows the "five horizontal and two vertical" pattern, as shown in Figure 2. The "five horizontal" layers, from bottom to top, include the intelligent perception layer, cloud infrastructure layer, data layer, service layer, and application layer. The "two vertical" layers are the safety guarantee system and the standard specification system.

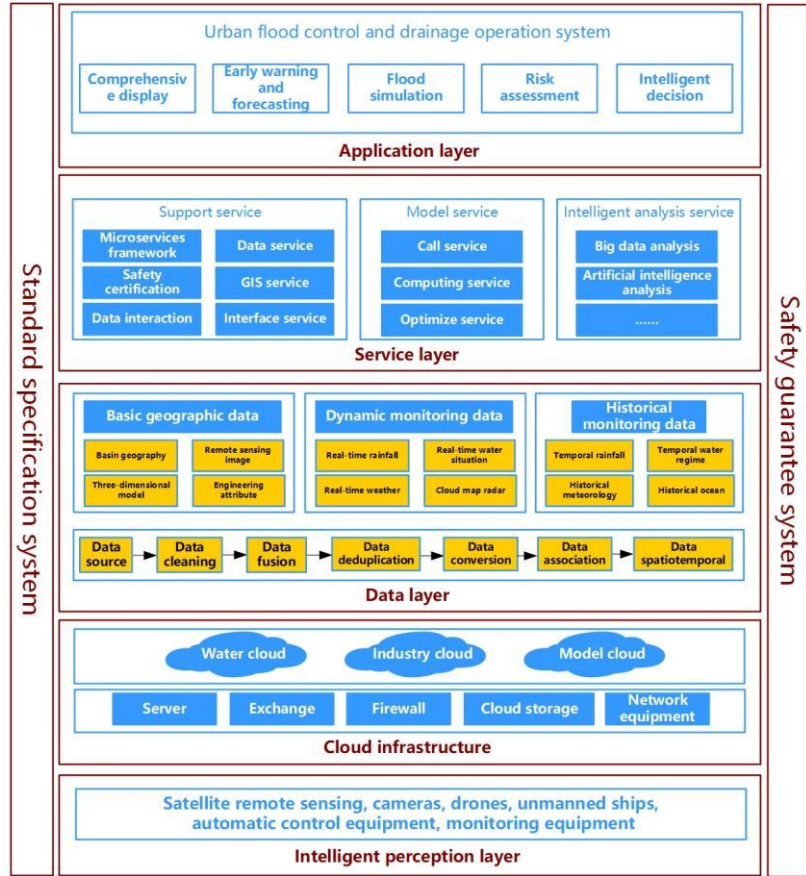


Figure 2. System Architecture Diagram

(1) Intelligent Perception Layer

The intelligent perception layer serves as the foundation of the urban flood control and drainage scheduling system. It utilizes various sensing devices, technologies, and methods such as IoT, mobile internet, navigation positioning, and video surveillance to collect elements, status, and event information of three major categories of water objects: river and lake water systems, water engineering facilities, and water management activities. This layer enables real-time monitoring and comprehensive perception of water objects.

(2) Cloud Infrastructure Layer

The urban flood control and drainage scheduling system is deployed in a distributed manner based on a cloud platform. The cloud platform integrates hardware devices including hosts, cloud storage, networks, and other necessary monitoring tools through virtualization software. The integrated cloud platform infrastructure mainly includes networking, security, communication, and other components.

(3) Data Layer

By adopting a multi-source data aggregation approach and building on data governance and local data resource repositories, the system decouples and integrates data resources based on application requirements. It establishes an object-oriented data model and constructs a water resources spatiotemporal big data center for flood control and drainage scheduling based on a cloud environment. On this basis, data resource management tools are utilized to provide unified data support for upper-layer platforms and business applications.

(4) Service Layer

The platform service layer serves as the foundation and core of business applications. It is built on a microservices architecture and deploys multiple microservices for spatial data targeting users. This layer enables rapid development, flexible deployment, elastic scaling, and extensive reuse. It mainly consists of support services, model services, and intelligent analysis services. Support services include microservice frameworks, data services, security authentication, GIS services, data

interaction services, interface services, etc. Model service platforms include model invocation services, computing services, optimization scheduling, etc. Intelligent analysis service platforms include basin, regional, and urban flood control and drainage engineering group scheduling simulation models, dynamic assessment models for flood disaster losses in urban areas, integrated fine-scale simulation models for basins, regions, and urban flood control and drainage, big data analysis, artificial intelligence analysis, etc.

(5) Application Layer

The application layer is the realization layer of platform functions. Based on the data resource layer and platform service layer, it fully integrates existing flood control and scheduling achievements and combines real-time flood control scheduling decision-making business requirements to form comprehensive applications such as comprehensive display, early warning and forecasting, flood simulation, dynamic risk assessment, decision support, water engineering scheduling, scheduling scheme selection, 3D display, GIS+BIM display, fine-scale flood simulation, etc.

(6) Standard and Security Assurance System

Based on the existing safety protection system and management regulations in urban areas, the standard and security assurance system is improved to provide a foundation for operation, hardware and software environment, and information security protection. At the same time, construction and operation management are implemented through systems, regulations, and standards.

3.3 Functional architecture design

On the basis of the overall framework of urban flood control and drainage dispatching system and regional needs, the flood control and drainage dispatching decision-making system is customized, which mainly realizes functional modules such as comprehensive display, early warning and forecast, flood simulation, risk assessment, project dispatching and decision support.

(1) Comprehensive display

Based on a map of river basin water conservancy and a region-urban spatial database, a map of flood control and drainage operation for urban flood control and drainage is built by integrating the information of water conservancy projects such as rivers, key reservoirs, hydrographic stations, sluice pumps, embankments and related monitoring stations, comprehensively displaying real-time monitoring information of water and rain conditions, typhoon storm surge, and analysis and prediction data. Users can conveniently, quickly and comprehensively find and master historical and real-time information such as meteorology, hydrology, industrial conditions and disaster situations, and display it in statistical charts and GIS graphics, so as to improve and enhance the overall water security perception information service ability.

(2) Early warning and forecasting

Relying on the "One map" spatial information integration platform for flood control and drainage operation, the visualization and alarm of rainfall, water situation and other routine real-time monitoring information are carried out. When the measured flood has occurred in the watershed area, the system reads the rainwater database in real time, and when the water level of each control section of the river reaches the warning level, the corresponding sluice pump that has reached the operation condition flashes different color warning lights according to the grade. When the flood is predicted to occur, the system simulates and calculates the forecast scheme. When the water level of each control section of the forecast river reaches the planned dispatching level of reservoirs, sluice pumps and other projects, the system will give early warning to sluice pumps that meet the commissioning conditions according to different time scales and flash different color warning signals to provide judgment and decision basis for the joint dispatching of water project groups. To remind the flood control and drought control command department to conduct corresponding commands.

(3) Flood simulation

According to the need of simulating the characteristics of production and confluence of the basin, the Xin'an River Model, TOPMODEL distributed hydrological model and other water quantity prediction models were customized. According to the real-time and forecast rain and work information, the automatic forecast calculation is completed, and the forecast results are analyzed and counted. Through the coupling calculation of hydrodynamic models such as zero-dimensional regulation and storage, one-dimensional river network, two-dimensional river network, quasi-three-dimensional lake and pipe network model with hydrological model, the influence of regional flood diversion on the water level of river and pipe network, and the influence of the change of water level of river and pipe network on urban water accumulation are analyzed, and the simulation accuracy and reliability are improved.

(4) Risk assessment

By using UAV aerial survey point cloud data and advanced information technologies such as virtual geographic environment, BIM and 3D GIS, a typical regional virtual environment is constructed. Dynamic spatio-temporal simulation and deduction of flood and disaster risk impact assessment model are used to dynamically simulate the flood propagation process and visually and vividly display the flood inundation process. Through high-precision calculation of flood disasters in key areas, dynamic assessment of disaster losses in population, economic activities, road transportation facilities and other aspects is carried out to analyze the losses caused by regional and urban floods.

(5) Project scheduling

Based on the topological relationship between water conservancy projects, the layout of water conservancy projects is generalized, and the storage process of various water conservancy projects in river channel under various inflow conditions is simulated. In a small time scale, the refined scheduling process of hydraulic engineering is simulated when certain set requirements are met for different incoming water processes. Based on the risk assessment results, the optimization strategy of the optimization algorithm is applied to determine the scheduling modes of each water project in each calculation period under various constraints such as hydraulic power, scheduling and inflow, and the optimal flood control and drainage effects of various water projects are achieved by comparing the scheduling target results.

(6) Intelligent decision-making

Based on the real-time information of rainfall, water level, discharge and dispatching, a dynamic flood control model composed of water project, river course and target dispatching node is constructed. Intelligent algorithm is adopted to realize the push of flood control and drainage dispatching scheme based on the control of multiple dispatching target nodes. At the same time, man-machine interaction Settings are provided to further modify the application parameters of flood control and drainage projects such as reservoirs and sluice pumps, and carry out scheme trial calculations, which can generate one or more flood control project scheduling and operation schemes, and recommend the most suitable flood control and drainage scheduling schemes through comparison, so as to provide support for the collaborative decision-making of river basins, regions and cities.

3.4 System implementation Methods

The whole system is built based on the framework model of microservices. The back-end uses the idea compiler environment to establish the application service support system by using SpringCloud, redis, Elasticsearch and other technologies. The front-end uses Visual Studio Code as the compiler. Take react as the basic framework and integrate ewater engine for front-end display page development. First of all, based on the relevant data resources of the watershed, region and town spatial database, a map of flood control and drainage scheduling is constructed, and ElasticSearch is used to build a spatial big data analysis engine to achieve all-round, fast indexing and analysis functions of water-related spatial data. The deep integrated GIS technology provides strong technical support for the operation of flood control and drainage. Secondly, the core water

conservancy models such as hydrological forecast, flood simulation and disaster damage assessment are built, and the model service interface is standardized. Then we use Web Service to call data, model and other service interfaces to realize the calculation of the system background. Finally, through system integration, functions are customized to realize comprehensive display, early warning and forecast, flood simulation, risk assessment, project scheduling and intelligent decision-making.

4. Summary

In this research and design of urban flood control and drainage dispatching system, the construction of flood simulation model oriented to basin, region and town is the core, the method of multi-source data fusion is adopted to improve the spatio-temporal accuracy and accuracy of data, and the multi-model integration and invocation technology is used to complete the invocation and coupling between various models. From the perspective of business requirements, based on the cloud platform, the design idea of the overall framework of the system is proposed, and the overall architecture pattern of "five horizontal and two vertical" is formed. Under this framework, an urban flood control and drainage dispatch system integrated with detailed flood simulation, early warning and forecast, dynamic disaster assessment and real-time project dispatch is built to effectively improve the accuracy of urban flood forecast, flood assessment and flood emergency dispatch timeliness, and promote the modernization and scientific decision-making of urban flood control and drainage dispatch management. It provides the practical significance from theoretical research to application.

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