A Modular Framework of Distributed Hydrological Modeling System: HydroInformatic Modeling System, HIMS

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Abstract: Distributed hydrological models have been shown high light on because of the spatial variability of hydrological processes. On the other hand, the complexity of the hydrological processes, the multi-purposes of hydrological modeling and the availability of observed data have made it difficult to bring forward a hydrological model system for general use. It is always confused and time consumed to find a model of most fit to practical application because of the variety types of hydrological models. In this paper, the framework of a modular based distributed hydrological modeling system has been discussed. The system was so called Hydroinformatic Modeling System (HIMS), include hydroinformatic management system, data pre- and post-processing system, and hydrological model & function library. For the management and processing of spatial information, basic GIS functions have been integrated into system on the basis of SUPERMAP, which is component based GIS software. The hydrological function library (HFL), which represents different processes of hydrological cycle, was the core of the entire system. Distributed hydrological models of different scale were all established on the HFL. The HIMS has been applied to hydrological research in the Yellow River Basin and has reached to some success. However, since it is still in its trial version, much more work need to be done to improve it.

Key Words: distributed hydrological model, modeling system, modular, HIMS

1 Introduction

Developing advanced distributed hydrological models is desired for purposes such as scientific research and water resources management. However, the development and application of distributed hydrological models are affected by various factors including simulation purposes (flooding forecast and water resources management etc.), scaling and data availability; and they are facing challenges such as model adaptibility, handling of massive data and providing decision support for other tasks. Overcoming such challenges is the key of the success in the development of distributed hydrological models. This trend alters the form of traditional hydrological models. A practical distributed hydrological model should incorporate GIS, has a wide range of simulation functions and be able to extend its professional capacity. Eventually, the distributed hydrological simulation systems, which are based on database software, technically supported by GIS/RS application and integrated with resources management and decision making modules in open frameworks are established.

USGS, based on the MMS (Modular Modeling System), has been working with European countries to develop the OMS (Objective Modeling System), which is developed on JAVA platform and utilizes the internet to achieve data sharing. Moreover, USGS and BOR jointly develop the Watershed And River System Management Project (WARSMP), which serves the purpose of developing a decision support system that is easy to use, database-oriented and capable of handling complex resources management problems. The main highlight of WARSMP is the integration of broad range of simulation functions and the application in water and environmental resources management. This decision support system combines USGS' MMS and BOR's river tool. In general, the integration of different hydrological cycle models, modular framework and multi-objective simulation have become a significant trend in hydrological simulation.

2 Framework of HIMS

The general structure of HIMS (Fig. 1) consists of the hydro-information system, the pre- and post-simulation data processing systems and a hydrological model library. The hydro-information system is derived from SuperMap, a domestic GIS software, which is capable of analyzing and handling spatial data. It is the core for data management in HIMS, and it provides the initial input data and stores the intermediate and final simulation data.

The Data Management Interface (DMI) is responsible for transferring and converting data between different system components. The pre- and post-simulation data processing systems contains the Graphical User Interface (GUI), which provides a user-friendly platform for various tasks. The hydrological model library contains hydrological models of various scales and structures. The single event simulators enable users to customize the model in order to adapt to the characteristics of the study system. Moreover, the open modular framework of HIMS ensures the flexibility.

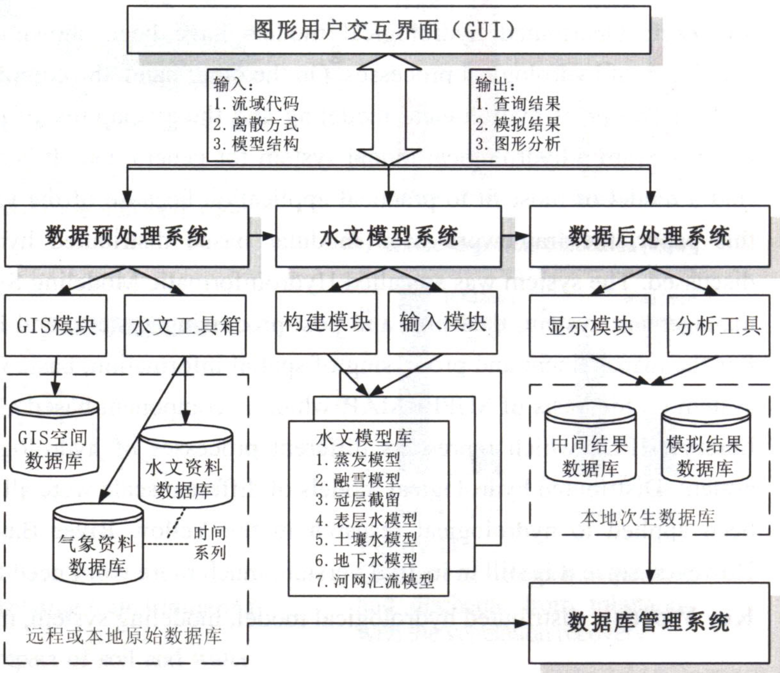

Fig.1 The Framework of HIMS

3 Hydro-Information System

The hydro-information system is based on SuperMap (Fig. 2), which provides the ability to handle and analyze spatial data, such as data conversion, mapping, spatial analysis, projection transformation. In addition, the GIS interface is dynamically linked to the Access Database in the background so that it can manage the database at any time. Any entry of the property data that have been edited, altered and enquired can be traced and displayed on the GIS platform.

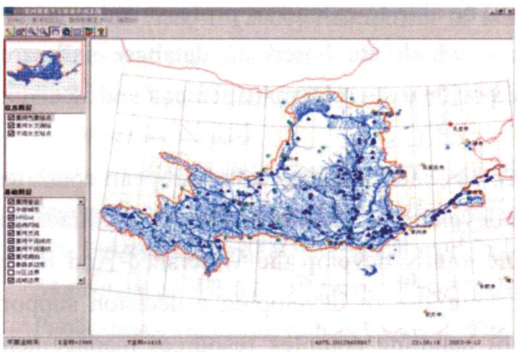

Fig.2 Hydro-Information System based on Supermap

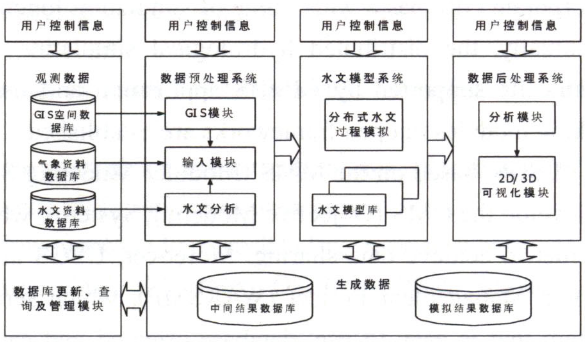

Fig.3 The flow chart of data information in HIMS

4 Data Processing System

The data pre-processing system of HIMS searches and processes spatial data and their attributes in order to satisfy the simulation requirements. Spatial data contain DEM, RS and the locations of hydrological stations etc. The preliminary processing of these data are performed on the hydro-information platform, such as format conversion, data trimming and projectory matching. The data are then converted into modeling input data such as physical properties of the basin, definition and indexing of unit basin(s), and digital river network data etc. Physical properties mainly include the time series of hydrological and meteorological data. The hydrological and meteorological data are lagged, synchronized and converted by the pre-simulation data processing system.

The data post-processing system is composed of a number of analysis and display modules, such as the statistical analysis module, 2D/3D graphical display module, and the text and spreadsheet viewing tools etc. Some modules can be repeatedly invoked by other components through GUI. As a future extension, resources management and decision support modules will be added to HIMS to enhance its functionality in water resources planning and management.

5 Hydrological Model Library

The hydrological model library includes the common methodologies for the simulation of virtually every hydrological process. It is developed on C++ platform. In the design of the hydrological functions, the first step is to define a process class, which has its own methodologies and properties, for a given hydrological process. Then, methodologies are specified for different hydrological processes, and properties are determined as the I/O database. Finally, the I/O database are structured for the hydrological processes (Fig. 3). The hydrological model library currently covers more than 100 methodologies and more than 600 variables for 9 surface hydrological processes.

HIMS has incorporated multiple distributed, semi-distributed and integrated hydrological models. Distributed models are mostly independently developed, which include daily and monthly/annually models, as well as single event models. Semi-distributed models include TOPMODEL for small spatial scales and bi-parametric models for large spatial scales. Integrated models includes Xinanjiang Model, and SCS model. Because of data availability and spatial variations of hydrological processes, HIMS also allows for customized hydrological models in addition to the hydrological model library, i.e. users have the discretion to choose and the simulation methodology according to the objective of the simulation and data availability.

6 Application of HIMS

Based on previous discussion, the preliminary design of HIMS is developed on Visual C++ Builder platform (Fig. 4). HIMS is then applied to representative small and medium sub-basins of the Yellow River, as well as the entire Yellow River basin. For example, the simulation errors for the Xiaolangdi-Huayuankou section, a representative small sub-basin (upstream of Lushi hydrological station, Luo River, which has an drainage area of 4,623 km2) are –9%~16% for peak flow and 7.7% for net precipitation. From the results, it is indicated that HIMS is applicable and it provides a new alternative for flooding forecast for the Yellow River basin.

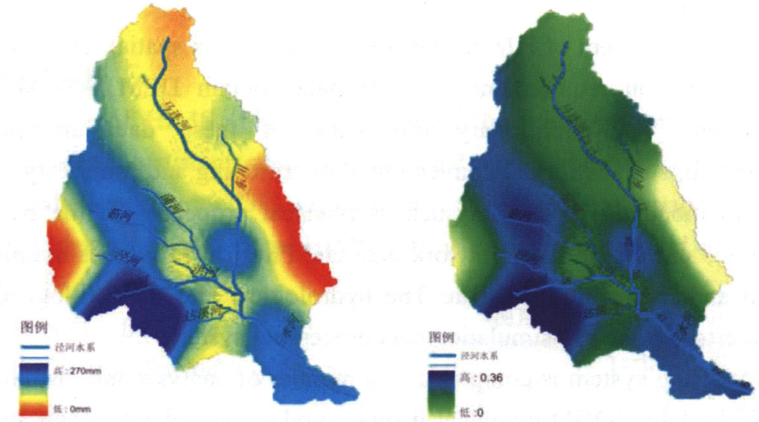

Fig.4 Application of HIMS in Jinghe River basin (left: runoff; right: runoff coefficient)

7 Summary

HIMS is an open and comprehensive hydrological cycle simulation system that is based on hydro-information platform and modular framework design. Such system covers different types of simulation problems, emphasizes on practicability yet accommodates general applicability, and has strong hydrological simulation, analysis and computation abilities. This system is developed based on SuperMap, a GIS software whose intellectual property is fully domestic. It integrates GIS and hydrological simulation functions; it constructs the simulation modules based on the classification of hydrological processes; and it achieves customized hydrological modeling through modular framework. HIMS includes three distributed hydrological models of different spatial and temporal scales so that it avoids the scaling problems that traditional hydrological models have when switching from one spatial and/or temporal scale to another. Therefore, HIMS allows for in-depth investigations of hydrological cycles at different spatial and temporal scales. HIMS currently has some practical values, however, it is still under development, and therefore, it is not yet commercially available.

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