INTEGRATION FLOOD FORECASTING WITH WEB-BASED SPATIAL DECISION SUPPORT SERVICES IN THE OAK RIDGES MORAINE AREA

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ABSTRACT

The complexity of spatial decision-making makes it difficult for individual organization to deal effectively with decision-making. Difficulty in linking data, analysis tools and models across organization is one of the barriers to be overcome in developing integrated spatial decision-making. Many researchers have been working on development of various models and decision support tools to address complexity in spatial decision-making. Many sources in the literature, including Decision Support System (DSS), Spatial Decision Support System (SDSS), Web-based SDSS (WebSDSS), Collaborative Spatial Decision-Making (CSDM) and Geographic Information Services (GIServices) demonstrate that considerable progress was made in the recent decades. However, there still exists some challenges for spatial decision-making and a growing number of researchers have realized that a new approach is needed to emphasize the benefits from a more open and collaborative decision-making process.

By facilitating an inter-organizational decision-making process through information exchange and knowledge, analysis tools and model sharing, collaboration can be used to resolve conflicts and reduce uncertainty in spatial decision-making. Web-based spatial decision support systems (SDSS) can increase public access and involvement in inter-organizational collaborative decision-making. However, most web-based SDSS are application-specific DSS consist of software, data, and model for a specific decision problem. Most of these systems utilize different types of Internet technologies and framework, and cannot share their data and model with each other. There are no generic tools that would accept user data online, supporting data, software and model sharing and hence act as a web-based decision support service. Therefore, it is required to develop a framework of the Web-based Spatial Decision Support Services (WSDSS), supporting web-based information exchange and knowledge, software and model sharing from different organizations on the web. This WSDSS can play an important role to establish a collaborative mechanism across organizational boundaries for spatial decision-making support.

From technical perspective, WSDSS supply three levels decision support and services: metadata services, geodata services and geoprocessing services. The first level is metadata services. Users use the metadata services as a front end to learn about all the types of data available in the system, as well as the types of models that can be used for analysis. Using metadata services, users can understand what data and model are available, how they have been collected, and who is responsible for managing and distributing the data and model. Using geodata services include Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Services (WCS) and filter Encoding etc al, users are shielded from the inconvenience of worrying about a variety of data sources, multiple data formats and data maintenance and update of the available distributed data because WSDSS detects and automatically resolve data heterogeneities in the underlying datasets, supplying data services and web mapping services for public. The decisions can be made faster and better when the decision-makers are provided with the most up-to-date, complete and correct information relevant to decisions for the problem they confront. The third level of decision support and services is groprocessing services. It has been realized that, in GIS servicers, distributed geoprocessing is very critical to help users in geodata manipulation, modeling and analysis. From an information service perspective, GIServices is value-adding processors, which add meaning value to data. In addition, methods and tools are likely to be of interest to a much larger collection of users than a given item of data. Effective sharing of methods and tools has potentially much higher return than sharing of data.

Yet it's unusual to see spatial information sharing and services among different organizations. Obstacles exist for the implementation of WSDSS. Those obstacles can be part technical, and part non-technical. The most significant impediments to sharing and services are institutional, organizational, standard and technical. This paper is mainly focus on the solution to technical difficulties.

The Oak Ridges Moraine (ORM) area is recognized as a major aquifer complex and a major source of drinking water for southern Ontario and one of the most heavily used ground water sources in Canada. The ORM area has always faced the impacts of extreme hydrological events. Water-related disasters, such as flood, not only have impacts on the ORM's economic and social well-being, but also exacerbate major environmental problems. To understand the mechanism of flood forecasting may provide scientific evidences for decision makers in assessment of water resources and development planning.

However, the mechanism of flood forecasting is complex, involving precipitation, drainage basin characteristics, land use/cover types, and runoff discharge. The application of flood forecasting models requires the efficient management of large spatial and temporal datasets, which involves data acquisition, storage, processing, analysis, and display of model results. The extensive datasets usually involve multiple organizations, but no single organization can collect and maintain all the multidisciplinary data. The possible access and usage of the available datasets remains limited, primarily because of the difficulty associated with the combining of data from diverse and distributed data sources. Difficulty in linking data, analysis tools, and models is one of the barriers to be overcome in developing a flood forecasting system. The current revolution in technology and online availability of spatial data, particularly with the construction of Canadian Geospatial Data Infrastructure (CGDI), much spatial data and information – such as National Water Data Archive and National Climate Data and Information Archive – can be accessed over the Internet from distributed sources. This facilitates the need in Canada for information sharing in support of decision making. Internet technology has been widely used for application development because of advantages such as platform independency, reductions in distribution costs and maintenance problems, ease of use, and sharing of information by the globally user [1]. This has resulted in research studies demonstrating the suitability of the web as a medium for the implementation of flood forecasting.

Web-based Spatial Decision Support Services (WSDSS) provide comprehensive support for information retrieval, model analysis and extensive visualization functions for decision-making support and information services. This paper examines the current state of the art and future prospects of hydrological models for flood forecasting, and develops a prototype WSDSS that integrates hydrological models, analytical tools, databases, graphical user interfaces, and spatial decision support services to help the public and decision makers to easily access flood and Flood-threatened information. Flood WSDSS helps to mitigate flood disasters through river runoff prediction, flood forecasting, and disaster information (flood discharge, water level and flood frequency) dissemination. The ultimate aim of this system is to improve access to flood model results for the public and decision makers.

This system has a multi-tier architecture consisting of presentation, business logic tier, and data tiers. The presentation tier is the interface for users to interact with system, users can submit requests from the presentation tier, and it also can be used as the system client viewer for accessing geographic data and analysis results. The business tier copes with the requests from the presentation tier. The components in the business tier, including web server, application server, metadata server, geodata server and spatial analysis and model analysis server, are used for handling requests and modelling analysis. The web server is the information exchange center between users and application server, supplies two-way communication between client and application server, and is used for receiving user requests, retrieving information, transferring requests to application server, and returning the results in the proper form to the explorer at HTML/HTTP standard. The application server is the core of this system: it responds with the request from users, and transfers the requests to a database server or model analysis server according to the requirements. The metadata server supplies metadata services for users. The geodata server accesses data remotely for model analysis, statistical analysis and spatial analysis, automatically coping with problems in data heterogeneities. The spatial analysis and model analysis server supplies spatial analysis, hydrological model and statistical model analysis and geoprocessing services for river runoff prediction and flood forecasting. The data tier includes all available distributed data sources from different organizations, including river runoff, water level and precipitation data from Environment Canada, and Land Use data from Natural Resources Canada etc. The Database server is used to manage those sharing database in this system, and it also supplies data services for the application server and spatial analysis and model analysis server.

The integrated components of this system include database, model base, interface, and spatial and graphic data display system.

1. Distributed and central management database: all spatial data are stored in GIS databases and all attribute data are stored in the Relational database management system (RDBMS). There are two sets of databases in this system: distributed database for model input and central management database for model input, running and result display. The distributed database allows for data acquisition from various agencies, including river runoff, water level and precipitation data from Environment Canada. The central management database stores data for model input, running and result display. Spatial data management is either as file based or spatial databases.
2. Model base: several models are integrated to support decision making, including hydrological models for runoff prediction, water level prediction, and flood frequency prediction.
3. Interface: a multiple-level web-based interface needs to be developed, through which the distributed database, the model base and the spatial decision services can be integrated. Users can submit their requests through this web interface and the prototype WSDSS will publish result map to users through this interface.
4. Spatial and graphic data display system: WebGIS supplies users the functions to be able to easily visualize model output results in map such as runoff prediction, water level prediction and flood frequency prediction. The implementation of the web visualization system is supported by ESRI ArcIMS.

[1] Peng, Z.R., and Tsou, M.H. 2003 Internet GIS: Distributed Geographic Information Services for the Internet and Wireless Networks. Hoboken: John Wiley & Sons.