Introduction to Computing and Computational Issues of Distributed GIS

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"GIS is only a technology and the remaining issues for GIS are to market it and make it more widely adopted." We often encounter such a challenge while presenting research issues of GIS in various occasions. Is the challenge a valid one? If GIS refers to the traditional system according to the definitions of GIS found in many introductory GIS textbooks and with years research from various places (such as the NCGIA led by Goodchild), then the challenge could be a valid one, as the technology for desktop GIS has reached a reasonable level of maturity. But if we go beyond just using commercial GIS products and start realizing the intersections between GIS and related disciplines, there are still a large number of research issues that need to be addressed. These issues are multidisciplinary issues that can only be addressed thoroughly through the collaborations between researchers in GIS and related disciplines.

In this special issue, we focus only on specific aspects of this new dimension on GIS research—the combination of GIS and Distributed Computing, and how the resulting functions can support the development of complex application systems. As computer networks are essential in supporting computing infrastructure and meeting the needs of today's enterprise operations, marrying GIS with computer networks has formed various types of distributed GIS, such as Network GIS (Yang et al., 2005), Internet GIS (Peng and Tsou, 2003), Intranet GIS, Wireless GIS, Distributed GIServices (Yang and Tao, 2005), Web GIS (Plewe, 1997), and Location Based Services (Jiang and Zipf, 2005). To distinguish these concepts and to give clearer definitions of these concepts, Yang et al. (2005) argued that all of them are Network GIS characterized by geographically dispersed in the allocation of geospatial information resources and geospatial computing. Yang et al. (2005) also pointed out that the distributed GIS is a higher level network GIS with all details transparent to users as computer scientists define *distributed as transparently access to computing resources*. All other terms above refer to different types of Network GIS with different communication infrastructures, such as the Internet, intranet, and the Web. In this special issue, we use *Distributed GIS* to refer to a Network GIS that provides a geospatial computing platform for supporting decision making, but the implementation details are transparent to users.

It is generally recognized that Xerox established the first map server online in 1993, an event that might have triggered the flourishing of Distributed GIS in subsequent years. In 1994, the importance of sharing geospatial information and geospatial computing using Distributed GIS was recognized nationally and internationally. For example, in 1994, the Federal Geographic Data Committee (http://www.fgdc.gov/) was initiated to build a National Spatial Data Infrastructure (NSDI) within the United States for sharing geospatial data across the country. Open Geospatial Consortium (http://www.opengis.org) and International Standards Organization / Technical Committee 211 (http://www.iso.org) were also formed in the same year in order to address interoperability issues related to Distributed GIS. Scholars in China also recognized the importance of research in Distributed GIS, and a national ninth-five-year-plan project was initiated in 1996 at Peking University to *build the national spatial information infrastructure of China*.

From the commercial perspective, Distributed GIS has a business volume of tens of billions of dollars. Though the majority of the activities are found in developed and western countries, developing world is catching up in using Distributed GIS to provide various types of services. On the other hand, there is still a significant number of research topics remained to be addressed, especially, within complex scientific application contexts, such as a disaster management and rapid response system. These research topics could be: for example, (1) the geospatial computing platform for supporting complex scientific applications, (2) the reliability and timeliness of the information, (3) the simulation interoperability among the earth observing inputs, simulation input/output, decision support system input/output, (4) the impact analysis of such a system and the feedbacks for improving such a system.

National Science Foundation (2005) of the United States, in collaboration with the National Institutes of Health (NIH) and the National Oceanic and Atmospheric Administration (NOAA) recently announced a new program called *Dynamic Data Driven Application Systems* to address this type of complex problems. NASA established the Geospatial Interoperability Office (GIO, http://gio.gsfc.nasa.gov) in 2004 at Goddard Space Flight Center to address the interoperability issues among different decision support systems and solution

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networks for earth science applications. China initiated a national 973 (an initiative within china for promoting fundamental research) project in 2005 named *Earth Observing Data, Spatial Information, and Geospatial Knowledge Transform Mechanism* to address issues of the emerging scientific mechanism, computing issues, geospatial information fusion, and intelligent services. These national and international initiatives suggest that there is a need for interdisciplinary research to utilize geospatial information to improve decision support systems within which Distributed GIS plays a key role.

The objective of this special issue is not to provide solutions to the scientific problems embedded in the type of complex systems discussed above. Instead, we attempt to identify computing and computational issues of distributed GIS that can potentially contribute to the formulations of solutions to those complex scientific procedure and problems. Seven papers were selected from a stringent review process, covering topics ranging from system architecture (the first three papers), to fundamentals and/or practical computing issues (the fourth through the sixth papers), and research challenges (the last paper). We first solicited papers to be presented in the two organized AAG sessions on Distributed GIS at Denver, Colorado, 2005. Then, we selectively invited authors who were participated in the two sessions to submit full papers. Finally, all papers were reviewed by at least two anonymous reviewers and one guest editor, and eventually seven papers were selected based on the review results.

Cai examined how to extend distributed GIS to support geo-collaboration in crisis management. Specifically, his paper addresses how the design of a distributed GIS can support the communication and collaboration among members of a geographically distributed crisis management team. A team mental model was proposed to support the computational approach to enable collaborative geographic information dialogues in spatial decision-making contexts. A simulated crisis management scenario was used to illustrate how visual displays can actively mediate human-human dialogues in real world applications.

Zhang and Tsou presented a five-tier architecture for Grid-enabled GIServices web portals to support high-level intelligent Internet GIServices. The architecture utilizes Grid computing, Semantic Web, software agents, and geospatial ontologies to provide advanced semantic search and query functions for distributed GIServices. The architecture is intended to provide a blueprint to identify potential technical challenges to implement intelligent Internet GIServices.

Di proposed a framework for developing Web-Service-Based Intelligent Geospatial Knowledge Systems based on the current advancements in geospatial interoperability, knowledge management, and knowledge mining. The framework includes several components, such as on-demand information discovery, intelligent question answering, and self-evolving mechanisms. Geo-object and geo-tree concepts were suggested to facilitate the mechanisms.

Zhu and his co-authors illustrated how a distributed GIS can increase the efficiency and effectiveness of resource management operations through its application in Shanghai, China. They demonstrated how to handle four essential computing issues within a distributed GIS: (1) management of large images, (2) time dimension management, (3) network communication of geospatial information, and (4) spatial data access.

Kou and his co-authors presented a system for disseminating geospatial information by leveraging the database, data analysis, and Internet technologies. The proposed system can integrate real-time data and support effective data analysis and visualization through a user-friendly interface.

Web Services technologies are widely recognized as an important set of technologies having significant contributions to the interoperability of distributed GIS. The paper by Yi and Huang illustrated how XML and related technologies can be used in such a distributed GIS environment. They examined how XML technologies can be applied to interoperate heterogeneous resources and presented an example of integrating various types of information, e.g. weather, road and traffic conditions, to assist travelers in making better-informed trip decisions.

Finally, Chen and her co-authors reviewed the evolution of GIS and distributed GIS. They classified the evolution of distributed GIS into three stages: emerging, evolving, and advanced stage. Based on the computing requirements for the advanced stage distributed GIS, they identified the computing and computational challenges for this type of distributed GIS. These challenges include system performance, user interface design, interoperability, data integrity, spatial data mining capability, and data and system security.

We recognize that existing literature has addressed computing and computational issues of distributed GIS. Several edited volumes along this line of research include the one by Open Shaw and Abrahart (2000) on *GeoComputation* and the one by Healey et al. (1998) on parallel computing in GIS. However, we believe that this special issue focusing on the computing and computational issues of distributed GIS will provide additional insight to the literature. The knowledge we gained from this special issue project will likely help developing a geospatial computing platform based upon distributed GIS and supporting the needs to develop new scientific applications using distributed GIS technology.

During the process of publishing this special issue, the willingness of all authors in sharing their research results and collaborating with the guest editors made the publishing of the issue possible. We are extremely grateful to all the anonymous reviewers for their thoughtful and constructive

suggestions in improving the quality of these manuscripts. Their efforts played an important role to get all these papers published eventually.

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