EDITORIAL
Distributed and mobile spatial computing

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Abstract

Recent technological advances in wireless sensor networks and mobile computing devices combined with novel distributed computing architectures are driving new research into distributed and mobile spatial computing. This special issue reports on progress made in this field through a selection of papers that followed from the workshop on distributed geoinformatics and sensing, ubiquity, and mobility (DGSUM'07). The volume contributes to the theory of distributed and mobile spatial computing by a selection of articles on algorithms for environmental monitoring and emergency management; knowledge acquisition in navigation; and geosensor research management and policy.

Key words: Distributed spatial computing, mobility, geosensor networks, ambient spatial intelligence.

This special issue of *Computers, Environment and Urban Systems* reports on progress in distributed and mobile spatial computing. The papers collected in this special issue were selected from an open call, prompted by the workshop on *Distributed Geoinformatics and Sensing, Ubiquity, and Mobility* (DGSUM'07 [1]) held on 19 September 2007 at Mount Eliza, Melbourne, Australia. DGSUM'07 was held in conjunction with the 8th *International Conference on Spatial Information Theory* (COSIT'07 [2]) and was a joint activity of the *ARC Network on Intelligent Sensors, Sensor Networks and Information Processing* (ISSNIP [3]) and the *International Society for Photogrammetry and Remote Sensing* (ISPRS [4]). In a true interdisciplinary spirit, the workshop brought researchers in spatial information theory together with researchers from specific spatial problem domains, such as ecology, natural resource management, marine science, transportation and human navigation, and emergency management and logistics. The delegates presented papers, reported on progress in the field and discussed a research agenda and funding opportunities.

The workshop followed a growing interest in combining recent technological advances in wireless communication, mobile computing devices, and novel distributed computing architectures. In 2004, the first workshop on Geo Sensor Networks in Portland, ME, heralded the arrival of *geosensor networks*, a new and exiting technology for monitoring highly dynamic geospaces [2]. The workshop identified the potential of emerging *Wireless Sensor Networks* (WSN, [3]) for geospatial applications and consequently, coining the term "geosensor network" as a WSN monitoring phenomena in geographic space. It was acknowledged that the unique set of constraints in such spatially distributed systems present challenges to conventional spatial computing approaches. Whereas conventional spatial computing is based on the integration of captured spatial data in powerful and omniscient databases, distributed and mobile systems increasingly blur the distinction between spatial data capture and processing.

Now, five years later, the diversity of contributions collected in this volume reflects the community's progress. What was initially motivated by the emergence of new technology has grown into a maturing research community, discussing fundamental scientific questions that go well beyond simply building and using geosensor networks. As such, a theory of distributed and mobile spatial computing aims to:

- investigate to what degree and in what way spatial computing data structures and processing techniques can be adopted for distributed and mobile systems;
- develop new applications and algorithms that are unique to distributed and mobile systems, for example, exploiting spatial autocorrelation and mobility;
- promote applications of distributed and mobile spatial computing in science and industry.

The papers included in this volume all address one or several of the challenges detailed above. The following

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[2] www.cosit.info
[3] www.ee.unimelb.edu.au/ISSNIP
[4] www.isprs.org

paragraphs introduce the four papers and put their contribution into context.

The first paper discusses algorithms for environmental monitoring, the core business of geosensor networks. Umer et al. present an algorithm for optimizing queries that collect sensor readings from a wireless network. Their monitoring queries exemplify two key strategies for successful distributed spatial computing. First, the algorithm processes the sensed data locally and hence no hard-to-maintain and costly global information about node locations or network connectivity is required. Second, the algorithm exploits the fact that the geospatial phenomena to be monitored are spatially interrelated. Since physical phenomena are spatially correlated, the query selects spatially co-located nodes. When changes occur to the physical network over the lifetime of long-lived queries, the algorithm adapts data collection accordingly. The paper furthermore illustrates how intensive simulations are used to speed up algorithm development and knowledge discovery in the field. Many spatial applications assume dense networks of thousands of nodes. However, most geosensor networks in research labs today are limited to dozens rather than thousands of nodes. As a result, implementating and testing new algorithms in physical networks remains, for the timebeing at least, impractical and expensive, and often impossible. In extensive simulations Umer et al. show that their algorithm is more energy efficient than comparable data collection schemes and can also adapt to changing environmental conditions in an efficient manner.

The second paper also has a computational core, but concerns the application of novel data structures and algorithms in the context of disaster and emergency management. Lee and Lee present a Delaunay triangle-based data structure supporting various "what-if" queries to handle different phases in emergency management, including mitigation, preparedness, response and recovery. They argue that higher order Voronoi diagrams are well-suited to distributed and mobile emergency management. For emergency response, for example, k-nearest emergency units may be required to cooperate and collaborate in order to reduce damage (emergency units as in hydrants in urban fires, electronic pumps in floods, and ships in oil-spills). In the theory section the authors explain how higher order Voronoi diagrams can support nearest neighbor, zoning, location, and routing queries for emergency response. The applications section provides ample examples of how higher order Voronoi diagrams can be used for emergency management. The study region of Townsville, a tropical city of northern Queensland, Australia, subject to periodic tropical cyclones, strong winds, and heavy rains, serves as a test bed for their approach.

The third paper in the volume addresses the important issue of human-computer interaction in mobile geospatial applications. Willis et al. present an empirical study of spatial knowledge acquisition in a mobile navigation scenario. The authors investigate the question of how the increasing use of GPS-based mobile navigation aids may influence what we learn about the space we move in. Two test groups were asked to "learn" the same standard urban environment through (a) studying a conventional map of the environment without actually being in the environment, and through (b) navigation with a mobile navigation device (so-called "mobile map") in the environmental setting itself. Their learning success was then compared through a series of spatial estimation tasks connected with orientation, Euclidean distance, and route distance. The authors argue that mobile map users acquire a more fragmented and regionalized knowledge representation. The authors conclude with implications of their findings for learning with mobile navigation applications in urban environments and conclude with concrete suggestions for the design of better mobile maps.

Finally, in the forth paper, de Freitas et al. assume the smoothly operating geosensor network infrastructure that other papers address directly, but instead ask how to facilitate the successful adoption of geosensor network technology in research and practice. Reflecting on several years' experience in maintaining a real-time marine and coastal geosensor network along the Great Barrier Reef, Australia, the authors identify the main drivers and obstacles to the establishment of environmental sensor systems. In a concrete participatory study based on interviews and on-line surveys, the authors investigate the complex relationship between scientists and technology providers (information suppliers) and policy and decision makers (information users). The authors point out that even though information suppliers and users share high-level interests, the parties foster significantly different research questions and there remain striking communication deficits. The paper provides concrete advice on how to overcome such obstacles.

This special issue coincides with a noticeable increase in distributed and mobile spatial computing topics discussed at conferences in the field, such as GIScience 2008 [5] and ACM GIS 2008 [6]. This special issue is part of that ongoing progression of research into, and ultimately use of distributed and mobile spatial computing in various applications, including environmental monitoring, health and medicine, and industrial repair and maintenance applications. Ultimately, these advances hold the potential for the development of ubiquitous computing technologies, embedded within dynamic, built and natural environments, with the spatial intelligence necessary to monitor, report on, and even act on geospatial events occuring in those environments. Extending the vision of ambient intelligence (AmI) in ubiquitous computing [1], we refer to our vision as *ambient spatial intelligence* (AmSI). We can imagine farmers querying fields for a spatial summary of recent carbon sequestration across that field; marine scientists alerted to the emergence of regions of abnormally high

[5] www.giscience.org
[6] acmgis08.cs.umn.edu

sea temperature in sensitive habitats; or fire fighters coordinated and supervised in a bush fire using real-time measurements in the temperature field. We believe the papers presented in this volume are another step towards this vision of ambient spatial intelligence.

Before presenting the four special issue papers themselves, we would like to extend our sincere thanks to all the special issue reviewers, who contributed timely and thorough reviews; to the journal staff and Editors-in-Chief, initially Paul Longley and then Jean-Claude Thill, for their support and input; and especially to all the authors who submitted papers to the special issue. Further, we would also like to acknowledge the important role of those who contributed to the DGSUM'07 workshop, from which this special issue grew, including: Marimuthu Palaniswami and ISSNIP for generously supporting the keynote and providing student travel scholarships; DGSUM'07 workshop co-organizers Lars Kulik and Egemen Tanin[7] and student helpers Muhammad Jafar Sadeq and Mingzheng Shi; keynote speaker Pavan Sikka for an inspiring talk and finally all the participants at DGSUM'07 in beautiful Mount Eliza.

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[7] Although Lars Kulik and Egemen Tanin were DGSUM'07 workshop co-organizers, as special issue paper coauthors neither were involved in any editorial capacity in this special issue.