

The Significant Growth of GIS

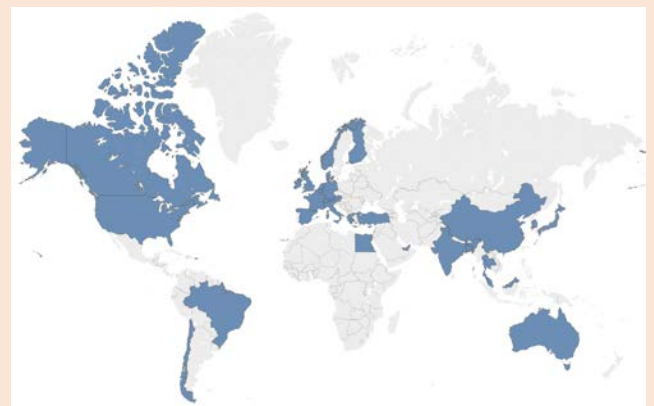
The “Encyclopedia of GIS First Edition” has been well received by a broad audience in industry, government and academia. By 2016, the cumulative downloads via Springer have exceeded 160,534 not counting additional downloads via other web-sites such as Google Books. Furthermore, it has received numerous recognitions such as the CHOICE outstanding title award. During this period of time, we have witnessed numerous significant advances in mobile technology and disruptive development in business that are transforming the world: the widespread use of smartphones, the increasing popularity of mobile apps, the wide deployment of location-based services (LBSs), the fast-growing taxi-hailing services like Uber, the evolution of mobile social networks, and more recently, the global interests in big data, unmanned aerial vehicles, and self-driving vehicles to improve people’s lives. Nowadays, there are over one billion GPS users, exceeding the number of Microsoft Windows users. While various disciplines have been contributing to these new advances, spatial computing and GIS techniques no doubt are playing a key role here. For instance, localization is a fundamental issue for smartphones, connected and self-driving vehicles, unmanned aerial vehicles, taxi-hailing services, etc. Location information and location privacy are the essentials of LBSs. Check-in recommendation is a key function of mobile social networks. The study of spatial big data, such as Global Positioning Systems (GPS) traces of vehicles and global climate data, help people better understand human mobility patterns as well as Earth climate change. Consequently, an influential 2011 report on big data from McKinsey included a chapter on location-based big data.

To acknowledge the growth, the Association of Computing Machinery (ACM) formed a special interest group namely, SIG-Spatial, and its annual meeting attracts over 300 attendees. In addition, the Computing Research Association’s Computing Community Consortium organized a multi-sector multi-disciplinary workshop titled “From GPS and Virtual Globes to Spatial Computing 2020” at national academies in 2012 to assess the state of the art and catalyze new research visions. A summary of the workshop report appeared in the Communications of the ACM in January 2016 as the cover article titled “Spatial Computing”. In summary, experts in GIS related fields and researchers from other disciplines have shown strong interests in understanding these new spatial technologies and developments. Therefore, we believe it is the time to develop the second edition of the encyclopedia and include entries on the new emerging topics.

The Second Edition of Encyclopedia of GIS

The second edition of Encyclopedia of GIS provides us an opportunity to enhance topic coverage and content timeliness of the first edition. While over 200 entries across 50 different fields were included in the first edition, there are still a few important topics left out, such as basic concepts in GIS and GPS. As suggested by GIS colleagues, we have included some of these topics in the second edition. Moreover, new research advances on some existing fields of the first edition are also updated either by adding new entries or through the revision of existing entries. The contributors of this book come from 31 countries in all the continents except Antarctica.

The second edition inherited all the key features from the previous edition. Typical entries are 3,000 words with sections such as definition, scientific fundamentals, application domains, and future trends. Regular entries include key citations and a list of recommended reading materials regarding the literature. The encyclopedia is also simultaneously available as an HTML online reference with hyperlinked citations, cross-references, four-color art, links to Web-based maps, and other interactive features.



The contributors come from 31 countries of 6 continents (All except Antarctica).

Free Online Access in 7,700 Institutions and via Google Books

Encyclopedia of GIS is included in the Springer package available in over 7,700 institutions worldwide as well as on third-party websites such as Google Books. At the University of Minnesota, the Encyclopedia of GIS has been used as teaching materials in spatial computing and spatial database courses at no cost to students. Its articles were used for the Fall 2014 Coursera’s massively open online course titled “From GPS and Google Maps to Spatial Computing,” with over 21,800 students from 182 countries. We hope that the second edition could continue serving the research community and the general public as a helpful introductory material to GIS, a resourceful research reference, and an illustrative GIS textbook.

Print Edition

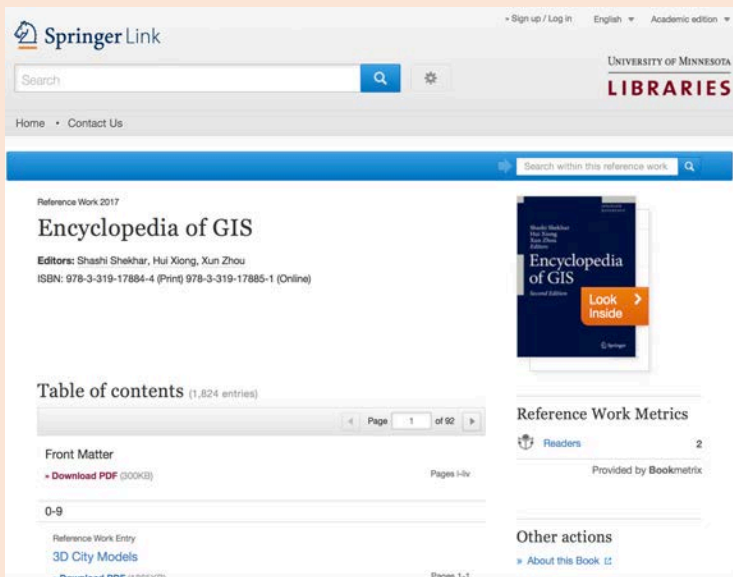
2nd ed. 2017. LIV, 2507 p. 1054 illus., 507 illus. in color.
ISBN: 978-3-319-17884-4

eReference

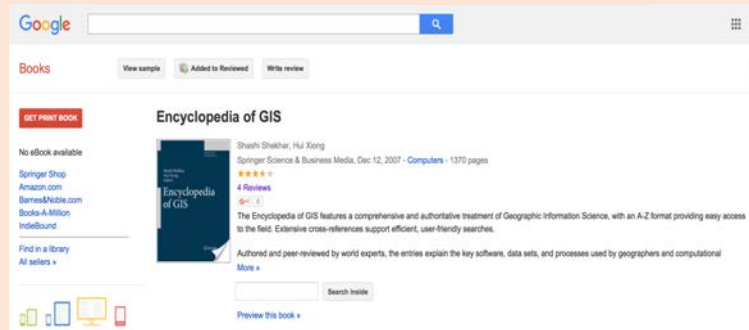
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New Fields and Topics

The second edition includes 25 additional fields that are either previously absent from the first edition or recently emerged as new research topics. Each field has typically 3–10 articles. These fields include spatial computing infrastructure, spatial cognitive assistance, volunteering geographic information (VGI), GPS-denied environment, statistically significant spatiotemporal pattern mining, mobile economy, mobile recommender systems, spatial network routing, spatial optimization, web-based GIS (industry perspective), location-based recommendation systems, linear anomaly window detection, intelligent transportation, GPU-based spatial computing, spatiotemporal analysis of climate data, geospatial weather and climate nexus, spatial statistics, concepts in spatial statistics, data science for GIS applications, 3D modeling and analysis, geometric nearest-neighbor queries, modeling of spatial relations, concepts in statistics for spatial and spatiotemporal data, high-performance computing in GIS, and trends. Furthermore, there are two fields, road network databases and constraint databases and data mining, which have been updated by the original editors with new concepts added or existing articles revised to accommodate more recent research results and technical advances.



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Praise For The First Edition

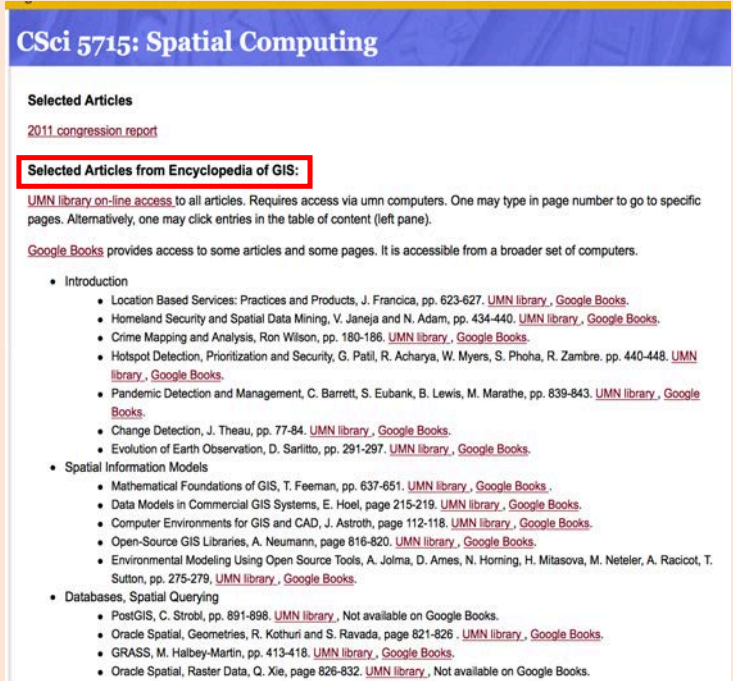
"The focus here, however, is on the mathematical and computational aspects of GIS This is very welcome to those practitioners who have been less exposed to some of the mathematical and computational aspects of GIS. This is also very welcome to the researcher or graduate student within any of the interdisciplinary areas that use GIS. ... I highly recommend it."

(Pascal V. Calarco, *ACM Computing Reviews*, November, 2008)

"This single-volume reference work is a highly welcome ... addition to the rapidly advancing field of geographic information systems. Peer-reviewed entries from over 300 contributors cover 41 topical subfields, with an overall emphasis on computational aspects of GIS. The volume is adequately illustrated with 723 figures and 90 tables in black and white. A full bibliography and concise list of entry terms are provided at the back of the work. ... Summing Up: Highly recommended. Upper-division geography students through professionals."

(C. E. Smith, *CHOICE*, Vol. 45 (11), 2008)

"The encyclopedia is divided into 41 fields, each one an important sub-area within GIS. ... the editors' organization of the material and comprehensive and systematic approach are superb and shall give students, eager readers as well as researchers an understanding of the topics in quite full depth and breadth. ... is lavishly illustrated with figures, graphs and tables, the design and execution of which are as perfect as the material they illustrate. ... it is sturdy and opens out nicely for study and reference." (Current Engineering Practice, 2008).



Used In-campus course at University of Minnesota

Backgrounds and fundamentals

In GSNs, however, node positions are often inexact or not available, and links between nodes can be asymmetric or might be intermittent, posing new challenges for formal approaches to GSNs.

- Cross-References**
- Geosensor Networks, Qualitative Monitoring of Dynamic Fields
 - Metereology
 - Voronoi Diagram

- Recommended Reading**
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Geosensor Networks, Qualitative Monitoring of Dynamic Fields

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Synonyms
Ambient spatial intelligence; Combinatorial map; Discretization of qualitative attributes; Qualitative spatial reasoning; Qualitative spatial representations

Definition

Environmental phenomena that vary continuously across regions of space and periods of time, such as changing sea temperature, concentrations of gas pollutant in the air, or levels of soil moisture, are called dynamic spatial fields. Information about dynamic spatial fields is important to a wide range of environmental applications. One of the goals of using a geosensor network (GSN) is to enable improved, more detailed monitoring of dynamic spatial fields. Individual sensor nodes in a GSN usually generate quantitative information. For example, a node might record a temperature of 23°C, located at coordinates 18.0AS, 146.40E at time 20:51:06 on January 7th 2007. However, the information needed by decision makers is typically qualitative, and

concerns the relationships between groups of nearby records. For example, an environmental "hotspot" has grown or moved. Generating qualitative information about dynamic spatial fields within a GSN presents a number of challenges. The most important challenge is to achieve qualitative monitoring using only local communication between nearby nodes. Resource limitations in GSNs mean that global communication, where any node can communicate with any other, is not scalable. Thus, studies of qualitative monitoring of dynamic spatial fields usually assume that at any time an individual node in the network does not have access to global knowledge about the state of the entire network, only to local knowledge about the state of its immediate neighbors.

Historical Background

Qualitative spatial reasoning is concerned with discrete, non-numerical properties of space. There are three main reasons for being interested in the qualitative (as opposed to the quantitative) aspects of geographic space (Galton 2000):

- Qualitative properties form a small, discrete domain; quantitative properties form a large, continuous domain, often modeled by real numbers. For example, temperatures in degrees Kelvin are modeled using the set of non-negative real numbers. Yet for some applications, temperature may be adequately modeled as an element from the set {hot, cold, warm}
- Qualitative properties are *supervenient*, or derivable from, quantitative properties. For example, in a particular application the numerical temperature 35°C may be described qualitatively as "hot".
- The boundaries between qualities normally correspond to salient discontinuities in human conceptualization of quantitative properties. For example, in coral reef monitoring ap-

lications, the qualitative boundary between "warm" and "hot" may be set to correspond to the quantitative temperature at which coral reefs are in danger of coral bleaching.

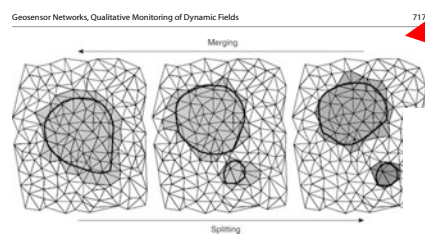
The literature contains many studies of different qualitative aspects of space, including relative distance (Hernández et al. 1995; Worboys 2001) and direction (Frank 1992; Freksa 1992), and in particular topological relationships between spatial entities (Egenhofer and Franzosa 1991; Randell et al. 1992).

Scientific Fundamentals

With respect to GSNs, the three general reasons for being interested in qualitative aspects of geographic space lead directly to three potential advantages of using qualitative monitoring of dynamic spatial fields in GSNs.

- Because qualitative properties form a smaller discrete domain than quantitative properties of space, processing and communication of qualitative information in GSNs can potentially be achieved more efficiently, using less resources, than for quantitative information.
 - Any quantitative information generated by sensor nodes can always be converted into a less detailed qualitative representation, although the converse is not true. Further, the inherent imprecision of qualitative information can help make sensor networks more robust to imprecision and other forms of uncertainty in sensor readings.
 - Using qualitative representations enables salient entities to be derived from complex dynamic fields, reducing system complexity and resulting in GSNs that are easier to design, construct, and query.
- Looking at the problem from the application perspective, it is possible to identify at least five distinct issues facing any GSN for monitoring dynamic spatial fields in the environment.

Clear problem definition



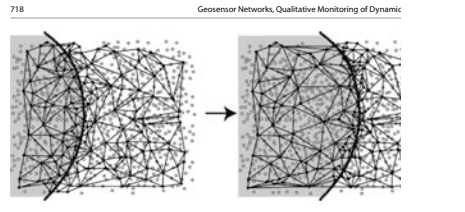
Geosensor Networks, Qualitative Monitoring of Dynamic Fields, Fig. 2 Local tracking of salient spatial data such as splitting and merging

information about the relative direction of it's immediate neighbors. Further, the inherent spatial imprecision in combinatorial maps, and related qualitative spatial structures, means that the resulting system can be more tolerant to imperfect information (e.g., the cyclic ordering of neighbors around a node is much less likely to be subject to inaccuracy than, for example, location systems that rely on exact coordinate locations or bearings from one sensor to another).

Having created appropriate qualitative representations, the second step is to develop local techniques for reasoning about these qualitative representations. In Fig. 2a region of dynamic spatial field (such as a high temperature "hot-spot") is being tracked through a GSN structured as a triangulation (using a combinatorial map). Assuming the region moves continuously, a variety of qualitative spatial events can be locally detected. In order for regions to split or merge, for instance, they must first go through an intermediate stage where a single node connects two distinct parts (Fig. 2, center). As a consequence of the combinatorial map structure, this node can locally detect that a split/merge event is taking place (see Worboys and Duckham (2006) for more information).

Key Applications

Dynamic spatial fields are of interest across enormous variety of environmental applications including meteorology, land cover change, fine science, water resources management, defense, and emergency management and response. In general, applications of qualitative monitoring of dynamic spatial fields can fall into



Geosensor Networks, Qualitative Monitoring of Dynamic Fields, Fig. 3 Georeponsive sensor network increased node activation in vicinity of the boundary of large region

broad categories. One category of use can be characterized as natural resource management, where decision makers use information gathered by GSN to manage scarce or fragile natural resources. Qualitative monitoring can help provide salient information to decision makers in a form that is more understandable and compatible with human conceptualization of dynamic spatial processes. Ultimately, such information can contribute to improved decision making. A second category of use can be characterized as scientific investigation of natural resources, where GSN are used by scientists to gather more detailed information about the environment than possible with conventional data logging techniques. In such cases, qualitative monitoring can assist in filtering data, screening out irrelevant data and highlighting high-level events of interest that can subsequently be investigated more closely.

Future Directions

As a relatively young area of study, qualitative monitoring of dynamic spatial fields has many important directions for future study, including:

Extensive illustrations

ability to manage complexity at every system level. Qualitative approaches provide one component of that complexity management, but further tools are required.

- Cross-References**
- Distributed Geospatial Computing (DGC)
 - Geosensor Networks, Estimating Continuous Phenomena
 - Geosensor Networks
 - Geosensor Networks, Formal Foundations
 - Localization, Cooperative

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Geosimulation

- High-Performance Agent-Based Geo-Spatial Modeling and Simulation

Future research directions

Reference list

Outline of An article

- Synonyms
- Definition
- Historical Background
- Scientific Fundamentals
- Key Applications
- Future Directions
- References

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