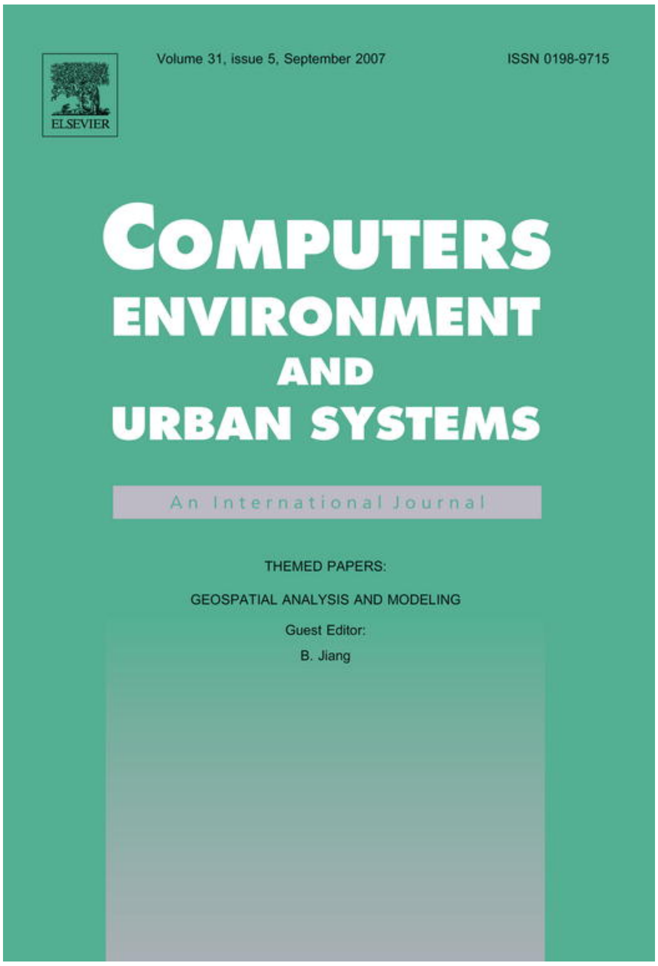
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Editorial: Some thoughts on geospatial analysis and modeling

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Abstract

This issue contains papers selected from the contributions presented at the 1st International Cartographic Association (ICA) Workshop on Geospatial Analysis and Modeling held in Vienna on the 8th of July, 2006 (http://www.hig.se/~bjg/ica/workshop/). The theme papers demonstrate partially recent developments in geospatial analysis and modeling for uncovering knowledge for various applications. This research has seen intensive growth over the past decade due to application needs and the increasing availability of geospatial information collected from various sources. The challenge for the research is to go beyond the conventional cartographic and geographic (mainly statistics-based) methods, and to develop more advanced and robust models for analyzing and mining geospatial information.

Keywords: Geospatial analysis and modeling; GIS; ICA

While retaining their significant role in collecting geospatial information from various sources and using various means, current Geographic Information Systems (GIS) have been gradually shifting to the quest of knowledge from massive geospatial information. This shift is mainly due to the significant advances of GIS technologies involving the Global Positioning System (GPS), remote sensing, digital mapping, and various other emerging location sensing technologies. Nowadays, we are surrounded by overwhelming information, most of which can be referenced to Earth, forming what is commonly called

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geospatial information. For instance Google Maps and Google Earth have integrated terabytes of satellite imagery, aerial photos, and digital maps, and ordinary people using their regular Internet connected PC can zoom from space right down to street level, and easily pinpoint their individual houses. However, it is geographic knowledge appearing in various forms of patterns, structures, relationships, and rules, rather than the spatial information assembled, that would significantly contribute to solving real world problems. It is in this respect that Geospatial Analysis and Modeling (GAM) find their unique position in Geographic Information Science (GISci), aiming at extracting knowledge from geospatial information.

Most of the current GIS software systems have some built-in GAM functionality or tools, developed from analytical cartography (or computer cartography) (Tobler, 1976) using a map metaphor. For instance, the well-know operations such as buffer and map overlay can help get an insight into potential patterns. In this respect, cartographic modeling (Tomlin, 1990) provides a range of tools embedded in most commercial GIS software. Maps are analytical tools to help geographers to "understand and theorize about the earth and the phenomena distributed thereon, or to change and modify it" (Tobler, 2000). This is indeed true, as GIS have become a tool for geo- and socio-scientists. In addition, other GIS-based GAM methods include those based on networks and digital elevation models.

There is a long tradition of well developed quantitative geography, mainly statistics-based, which contributes to understanding geographically distributed phenomena. Most of the GAM methods were developed prior to the GIS age, and have been re-examined in the context of GIS, e.g. ArcGIS extension Geostatistics Analyst. Well studied issues such as spatial autocorrelation play a significant role in understanding the nature of spatial phenomena. Waldo Tobler's first law of geography captures the autocorrelation pretty well, i.e., "everything is related to everything else, but near things are more related than distant things". This is also a major factor in how spatial statistics differs from conventional statistics that are based on random events. Another important issue is the Modified Areal Unit Problem (MAUP) (Openshaw, 1984) that often occurs in dealing with census datasets. These issues are a major reason for the cliché "spatial is special".

Conventional GIS-based GAM methods show various constraints in dealing with geospatial information, because the nature of geospatial information is massive, uncertain, dynamic and incomplete. Many new methods have been developed under the different flags of spatial data mining, geocomputation, geosimulation, and geovisualization. A key issue is to go beyond the map metaphor and develop more robust representations of space/time for GAM (Fotheringham & Wegener, 1999). For instance, time geography initially developed by the Swedish geographer Torsten Hägerstrand has been receiving a revival of research interest in the context of GIS for dealing with spatio-temporal information collected from GPS receivers. In addition, cellular automata (CA) and agent-based modeling, network modeling, and scaling hunting have featured in GIS conferences and journals.

CA and agent-based modeling provides a new paradigm for simulating dynamic phenomena, such as pedestrian movement and vehicle flow. These models are mainly developed from the interaction of individuals that constitute an interconnected system, which demonstrate some emerging patterns or structures (Benenson & Torrens, 2004). The modeling approach is particularly of use for analyzing and modeling socio-economic information that is linked to a geographic location. For example, Sweden has been building up a demographic database in Umeå (http://www.ddb.umu.se/index_eng.html) based on Sweden's civil registration over 200 years. With the database, researchers can track the course of an individual's whole life. These kinds of data sources can be dealt with by temporal modeling and agent-based modeling for extracting various kinds of knowledge. The agent-based modeling is mainly developed from complexity theory, adopting a bottom up approach in modeling. Along the same line of approach, network modeling also focuses on the interaction of individuals.

Recent advances in small world and scale free networks (Barabási & Albert, 1999; Watts & Strogatz, 1998) have triggered a disproportional amount of research interest in modeling geographic systems from a topological perspective. The conventional GAM methods show little advantage in modeling relationships and interactions, so a new topological oriented representation is needed (Batty, 2005). Distinct from conventional geometric representation, mainly for computing distances and optimal routes, the new topological representation is targeted for analyzing structures and patterns. For instance, it is found that a street-based topology is neither random nor regular, but a hidden order between random and regular graphs (Jiang & Claramunt, 2004). This topological analysis is now pervasive in a variety of disciplines including for instance biology, sociology, physics and computer science, and it constitutes also a key driver for the emerging science of networks (Newman, Barabási, & Watts, 2006). Both agent-based modeling and network modeling, different in essence and linked nevertheless, can further develop into robust models for GAM.

When dealing with massive information, statistical physics can help to illustrate some universal patterns. In terms of universality, power law (or scale free, scale invariance) has found its appearance in many geographic systems. A power law relationship between two variables x and y can be mathematically expressed as $y = kx^{-\alpha}$. A very typical power law is called Zipf's law (Zipf, 1949). In ranking world cities, the ranking relation can be expressed as the function $y = kx^{-\alpha}$, where x is rank and y population, and α a constant close to 1. Consequently, the law can be stated that for most naturally and socially related phenomena, small events are extremely common, while large events are extremely rare, e.g. earthquakes in nature and wealth in society. In terms of street connectivity, we found that α is around 2. This pattern can be further described as follows (Jiang, 2007): about 80% of streets with a street network have length or degrees less than the average value of the network, while 20% of streets have length or degrees greater than the average; out of the 20%, there are less than 1% of streets which can form a backbone of the street network. The pattern is a fingerprint of self-organizing cities. It also helps to explain why an image of the city can be formed in our minds from the perspective of streets.

I have added, in this short essay, a few thoughts about current and future development of GAM research. They are just a personal reflection, not intended to be exhaustive. However, with the continuous availability of geospatial information, the constraints of conventional cartographic and geographic based GAM will become more and more obvious. Thus seeking new GAM methods and tools will be a desired and expected development. This effort can be joined by a force from other research communities such as data mining and knowledge discovery in databases, information visualization, and statistical physics.

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