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Introduction to the Geographic Information Systems Minitrack

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Abstract

This paper discusses the status of geographic information systems (GIS) research in the fields of MIS. To do this, we define the technology as it relates to the IS field. We then discuss the research that has been done in other disciplines to study this technology. Finally, we present an outline of the research topics pertaining to GIS that appear to be of relevance to the IS field.

What is GIS?

The term Geographic information system (GIS) encompasses a broad range of tools for linking attribute databases with digital maps. However, GIS is really much more than this simple definition would imply. In fact, several definitions of GIS have been proposed, each of which suggest that GIS is much more than a mapping tool (see Table 1). A common theme in most of these definitions is the idea that GIS not only provide users with an array of tools for managing and linking attribute and spatial data, but they also provide users with advanced modeling functions, tools for design and planning, and advanced imaging capabilities. While many of these capabilities also exist in other types of systems such as visualization and virtual reality systems, GIS are unique because of their emphasis on providing users with a representation of objects in a cartographically-accurate spatial system and on supporting analysis and decision making. In essence, GIS are DSS generators when the decision context involves spatial locations.

A Brief History of GIS

The origins of GIS technology can be traced to the disciplines of geography and cartography, however researchers and developers from a variety of disciplines have contributed greatly to the development of GIS technology. For example, Mark, et al., (Mark, Chrisman, Frank, McHaffie, & Pickles (1997)) point out that organizations as diverse as the United States Census Bureau, the developers of the Minnesota Land Management Information System (MLMIS), and the scholars at the Harvard Laboratory for Computer Graphics were all working on GIS development projects as early as the mid-1960s. Yet, much of the real progress of the technology as a tool in business and industry took place in the decade of the '90s.

Table 1. Definitions of GIS (*after Maquire, 1991*)

Dueker (1979; p. 106) "a special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses."
Ozemoy, Smith, & Sicherman (1981; p. 92) "an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation, and display of geographically located data."
Burrough (1986; p. 6) "a powerful set of tools for collecting, storing, retrieving, at will, transforming and displaying spatial data from the real world."
Devine & Field (1986; p. 18) "a form of MIS [Management Information System] that allows map display of the general information."
Department of the Environment (1987, p. 132) "a system for capturing, storing, checking, manipulating, analyzing, and displaying data which are spatially referenced to the Earth."
Smith, Menon, Starr, & Estes (1987; p. 13) "a database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database."
Cowen (1988; p. 1554) "a decision support system involving the integration of spatially referenced data in a problem-solving environment."
Carter (1989; p. 3) "an institutional entity, reflecting an organizational structure that integrates technology with a database, expertise, and continuing financial support over time."
Koshkariov, Tikunov, & Trofimov (1989; p. 259) "a system with advanced geo-modeling capabilities."
Parker (1989; p. 1547) "an information technology which stores, analyses, and displays both spatial and non-spatial data."

Table 2. NCGIA Research Initiatives

Initiative 1	Accuracy of Spatial Databases
Initiative 2	Languages of Spatial Relations
Initiative 3	Multiple Representations
Initiative 4	The Use and Value of Geographic Information
Initiative 5	Architecture of Very Large Spatial Databases
Initiative 6	Spatial Decision Support Systems (SDSS)
Initiative 7	Visualizing the Quality of Spatial Information
Initiative 8	Formalizing Cartographic Knowledge
Initiative 9	Institutions Sharing Geographic Information
Initiative 10	Spatio-Temporal Reasoning in GIS
Initiative 12	Integration of Remote Sensing and GIS
Initiative 13	User Interfaces for Geographic Information Systems
Initiative 14	Geographical Analysis and GIS I: Spatial Analysis
Initiative 15	Multiple Roles for GIS in US Global Change Research
Initiative 16	Law, Information Policy and Spatial Databases
Initiative 17	Collaborative Spatial Decision Making
Initiative 19	The Social Implications of How People, Space, and Environment are Represented in GIS
Initiative 20	Interoperating Geographic Information Systems
Initiative 21	Formal Models of the Common Sense Geographic Worlds

Visit (http://www.ncgia.ucsb.edu/research/initiatives.html) for more information about NCGIA research initiatives.

This growth in the development and use of GIS is largely the result of two factors. First, as with many technologies, the widespread availability of high-end desktop computers that could process the complex geometric representations required to display spatial data was critical to the successful deployment of GIS in a variety of organizational settings. Second, the 1990 U.S. Census included a comprehensive mapping initiative that resulted in relatively accurate maps for the entire area of the United States. The results of this effort, referred to as the Topologically Integrated Geographic Encoding and Referencing system -- or TIGER for short, provided a relatively inexpensive data asset that could be utilized by a variety of users for any number of mapping applications. The importance of the TIGER data store cannot be overstated because access to GIS map data is often one of the principle impediments to GIS adoption and diffusion (Mennecke & West, 1998).

GIS Research: An Interdisciplinary Technology

GIS research is as diverse as that of most other technologies that are studied by MIS scholars. One of the most comprehensive efforts to study GIS has been undertaken by the National Center for Geographic Information and Analysis (NCGIA: www.ncgia.org). In the late 1980s, the NCGIA began a series of NSF-supported research initiatives that were designed to explore a variety of topics that pertain to GIS and related technologies. The 10-year project resulted in a total of 19 research initiatives (see Table 2).

An examination of these initiatives reveals both the diversity of research directions that are relevant to GIS as well as the opportunities that exist for MIS scholars to contribute their expertise to this important area. For example, although several of the initiatives are focused on technical issues associated with representing geographic data (e.g., Initiative 5, Initiative 8, etc.), several other areas have a focus on issues that have also been studied extensively by MIS scholars.

Of course, a number of GIS research projects conducted by MIS scholars have been reported in conference papers and journal articles. For example, one of us (Mennecke) has been involved in organizing conference mini-tracks on GIS as far back as 1992 (HICSS GIS Mini-track, 1992-1994; AMCIS GIS Mini-track, 1996-2000). In these venues, dozens of papers reporting on case studies, laboratory research, theory development, and other relevant topics have been presented and discussed. Furthermore, several research articles have appeared in leading MIS journals that have reported on research directly or indirectly studying GIS. For example, Grabowski and Sanborn (1992) examined a DSS supported navigation system and found that the success of the system could be attributed to its ability to disseminate information and reduce information overload. Crossland et al. (1995) examined the impact of using an SDSS on decision-making effectiveness and efficiency and found that SDSS use improved performance for three levels of task complexity and that user characteristics were related to outcomes. Pinto and Azad (1996) successfully applied a political framework to examine GIS implementation in two local government GIS implementation projects. Smelcer and Carmel (1997) examined the effectiveness of maps versus tables and found that maps are more efficient for a variety of levels of task complexity. Dennis and Carte (1998) extended research on cognitive fit theory (Vessey, 1991, 1994; Vessey & Galletta, 1991) to geographic tasks and found that a map presentation improved decision-making performance and efficiency for tasks involving adjacency relationships between geographic areas but a map diminished effectiveness when there were no geographic adjacency relationships (Dennis & Carte, 1998). Swink

and Speier (1999) examined the effects of data aggregation and dispersion on solving geographic problems and found that performance was lower on larger sized problems, data dispersion and disaggregation influenced performance, and a user's spatial orientation skills were related to outcomes. It is important to note that each of these articles was published in leading MIS journals, which points to the fact that GIS research is not only relevant to the MIS discipline but it is possible for scholars to publish their work on this topic.

Of course, much more research than we have space to write about has been performed by scholars from outside of the MIS area. As one might guess, geographers represent one of the principle groups conducting research on GIS. In addition, however, it is surprising how interdisciplinary the research on GIS has been. Other leaders in research on GIS include scholars from agricultural sciences, forestry, the biological sciences, economics, geology, government and regional planning, landscape architecture, library sciences, statistics, and many others. Of course, many of these areas study GIS as a tool for supporting endeavors in each of these respective disciplines. In these areas, as with the occasional publication about GIS that appears in MIS journals, there no journals focus exclusively on GIS. However, in geography and several disciplines that have, in effect, adopted GIS as a core topic of research, specialized journals have been organized to publish GIS research. For example, leading journals focused on GIS research include the following:

- The journal of Cartography and Geographic Information Science (http://www.survmap.org/commun42/cagis00.htm)
- Computers & Geosciences (http://www.elsevier.com/locate/compgeosci)
- GeoInformatica (http://www.wkap.nl/journalhome.htm/)
- IEEE Transactions on Geoscience and Remote Sensing (http://www.ieee.org/organizations/pubs/pub_preview/grs_toc.html)
- The International Journal of Geographic Information Science (http://www.taylorandfrancis.com/JNLS/gis.htm)
- The journal of the Urban and Regional Information Systems Association (URISA; http://www.urisa.org/journal.htm).

In summary, GIS is a topic that crosses functional disciplines and, as a result, a great variety of research has been published in this area. The interdisciplinary scope of GIS research has arisen because of the unique role that GIS has as a tool that integrates data using geography as the central organizing schema. For many tasks, this is a critical capability. Yet, much more research is needed to better understand the role of GIS in business, in education, in electronic commerce, and in other areas of import for developers and users of GIS technology. The next section concludes this introduction with a few of our comments about the future of GIS research.

GIS Research: Future Directions for the MIS Field

As has been the case in the past, geographers and scholars from related disciplines have charted a set of research priorities that are well considered and far reaching in scope. In particular, the NCGIA recently initiated Project Varenius (named after Bernhard Varen, a scientist who wrote the first textbook on geography), which is focused on the advance of geographic information science through basic research, education, and outreach (Goodchild, Mark, Egenhofer, & Kemp, 1997). Three areas of research will be the focus of this project:

- Cognitive Models of Geographic Space
- Computational Implementations of Geographic Concepts
- Geographies of the Information Society

Generally speaking, these focal areas pertain to three broad directions for research: research pertaining to human cognition and human-computer interaction, the design and structure of spatial databases and computational systems, and the impact of GIS on individuals, organizations, and societies.

It is difficult to suggest a program of research for the MIS field that does not fit into one of these broad areas. With this said, however, there are several specific topics that would seem to be particularly relevant to the MIS discipline that have, as yet, not been examined in a detailed manner. The following is a list of but a few of these foci for research:

Applications of GIS in Business: What is the role of GIS in business operations, management, and decision-making? Since much of the research conducted under the auspices of NCGIA and similar organizations have previously focused on public sector organizations, it is likely that future research will have a similar focus. Therefore, basic research focused on understanding the role of GIS in business is needed and offers a promising topic of research.

Implementation Issues Associated with GIS Technology: GIS presents many problems associated with implementation that are difficult to manage and overcome (e.g., see Mennecke & West, 1998). The availability of data, issues associated with data formats and interoperability, and political and strategic issues are all factors that need to be examined to better understand how GIS are best implemented, what works and doesn't work, and what causes implementation failures.

Applications of GIS on the Internet and in Electronic Commerce: A visit to many commercial web sites will reveal that geography is something that is very much of interest to businesses operating on the Internet. Whether it be a request for your zip code so that the nearest store to your location can be found or the generation of a map with driving directions, many web sites use spatial data, maps, and geographic representations to attract, manage, or service their customers. For example, a relatively new application in E-commerce is location-based services, where e-tailers link their goods or services to the location of the customer. Much research is needed to examine how GIS technologies are and how they could be used in electronic commerce.

GIS in Decision Support and Decision Making: Many of the research projects that have been published by MIS scholars in MIS journals have focused on the role of GIS in decision support and decision-making. This, therefore, seems to be a natural niche for the MIS discipline. Yet, much more research is needed to examine the role of GIS in this area. In particular, issues such as user knowledge, experience, and other individual factors that affect decision-making success need to be examined. Furthermore, the role of GIS in group and team decision making needs to be examined.

GIS in Organizational and Enterprise-wise Systems: GIS in the context of data warehouses, enterprise-wise systems, and similar large scales systems needs to be examined in greater detail. Although venders such as Oracle have spatial data products, it is not clear how these systems should be used, how they should be integrated with existing transaction and decision support technologies, and how they will impact organizational performance and success.

These topics represent only a few of the areas which MIS researchers would appear to have the potential to add value to the ongoing research on GIS. Certainly, since scholars in other disciplines have conducted the majority of the research on GIS that has been performed to date, there is a wealth of knowledge about this topic that MIS scholars should tap when conducting research in this area. For example, a question we have asked ourselves for several years is "Why haven't more MIS researchers examined GIS and related technologies?" One reason for this is the time commitment required to bring one's self up to speed on the GIS literature and on the GIS technology itself. Therefore, to move GIS research forward in the business and MIS area, we suggest that MIS scholars seek out knowledgeable collaborators from other disciplines in which GIS has an established research stream.

Conclusions

In conclusion, GIS is a rich area for research. Although the technology has existed for several decades, much more needs to be known about the applications of GIS technology in business, the impact of GIS on individuals and organizations, and how GIS should and can be developed and managed. Because MIS scholars are well positioned to contribute to the stream of research on GIS, this area offers a promising as well as exciting opportunity to expand to focus and scope of MIS research.

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