

Collaborative research should aim at improving GIS usability and success

BY MICHAEL F GOODCHILD



This article is the fifth in a series of articles based on papers originally presented by participants of the European Science Foundation's (ESF's) workshop on

geographical database (GDB) research in Aix-en-Provence, France, in March 1992. ESF organized three workshops this year to bring together leading European scholars in GIS research to discuss and identify priorities for collaborative European GIS research.

As director of the National Center for Geographic Information and Analysis (NCGIA), I am pleased that NCGIA was invited to participate in the European Science Foundation's Aix-en-Provence workshop on a collaborative European research effort in GIS. Information on the NCGIA, its activities and accomplishments is offered to provide a glimpse of the direction we in the United States have taken with regard to GIS research. In addition, I offer my personal suggestions for possible components of a European GIS research agenda, which are based on the objectives identified at the 1991 exploratory workshop in Davos, Switzerland, and my own experiences in GIS use and research.

NCGIA mission and achievements

NCGIA was established in late 1988 as a consortium of the University of California, Santa Barbara, California, USA; the State University of New York, Buffalo, New York, USA; and

the University of Maine, Orono, Maine, USA, following a solicitation issued by the US National Science Foundation (NSF) and with initial funding for five years. NSF allowed for a possible extension of funding to eight years, based on a review at the end of 1991. NCGIA's proposal for renewal of funding to November 1996 is under consideration.

NCGIA objectives are similar to those identified by European GIS experts, particularly the emphasis on basic research and technology transfer. NCGIA's formal mission is the advancement of geographic research of lasting and fundamental significance. Specifically, the center's activities are designed to:

- advance the theory, methods, techniques and applications of geographic analysis, based on GISs in the disciplines and professions involved in geographic research;
- augment the nation's supply of experts in GIS and geographic information analysis (GIA) in participating disciplines;
- promote the diffusion of analysis based on GIS throughout the scientific community and provide a conduit for disseminating information regarding GIS research, teaching and applications; and
- interact with individual researchers and organizations on a national and international basis.

NCGIA's mission has evolved since 1988, and we believe that it should continue to evolve, responding to developing themes within the research community, while remaining committed to basic and fundamental research. The GIS industry is large, dynamic and constantly transforming, and a research center that

proposes to interact with that industry, assist its development and encourage its responsiveness to the needs of the scientific community must be similarly adaptable and committed to evolution. We also are cognizant of the need to respond to changes occurring in the geographic and GIS research communities, particularly as the latter matures and defines itself.

The last three years have been busy for everyone involved in NCGIA, and we recognize the following major achievements.

- The consortium's 1988 proposal was successfully implemented, in detail, particularly with respect to administrative and management structures.
- Nine of the 12 original research initiatives and one new initiative were started. Three initiatives have been closed. Four additional initiatives were defined, and two are in an advanced stage of planning.
- The overall structure of research initiatives was steadily refined, and it worked well in managing research and involving the outside community in NCGIA activities.
- Significant research results were generated in several key areas of the research plan, marking substantial progress on the removal of impediments to GIS use.
- Progress was made in transferring results to the private sector, and in implementing results in vendor products. Other results are finding their way into data collection methods, modeling and analysis activities in assorted agencies and institutions.
- Reports of NCGIA research results were widely published in refereed

journals, books and conference proceedings. A total of 346 NCGIA-related papers were published as of October 1991, including 140 in refereed outlets. By December 1991, NCGIA published 12 books.

- There has been widespread acclaim and adoption of the NCGIA GIS curriculum. By late 1991, more than 800 copies were distributed worldwide, and several translations were under way.
- The publications series and newsletter were fully implemented, and operation of electronic bulletin boards and discussion networks were initiated.
- NCGIA attracted substantial additional funding support from government, industry and participating institutions.

NCGIA research

The center's research is based primarily around the concept of an initiative. Each initiative originates in a meeting of specialists, usually about 40, who discuss and refine the topic and an associated research agenda. The active research phase lasts from one to three years. The initiative is closed by a series of presentations of research results and a process of internal review. Following is the list of initiatives identified to date, with the dates of their specialist meetings and closings.

1. Accuracy of Spatial Databases (December 1988 - November 1990)
2. Languages of Spatial Relations (January 1989 - July 1990)
3. Multiple Representations (February 1989 - August 1990)
4. Use and Value of Geographic Information (May 1989)
5. Design and Implementation of Very Large Spatial Databases (July 1989)
6. Spatial Decision Support Systems (March 1990)
7. Visualizing the Quality of Spatial Information (June 1991)
8. Formalizing Cartographic Knowledge (1992)
9. Institutions Sharing Spatial Information (February 1992)
10. Temporal and Spatial Reasoning in GIS (1993)
11. Space-time Statistical Models in GIS (1992)
12. Remote Sensing and GIS (December 1990)
13. User Interface Design (June 1991)
14. Spatial Analysis and GIS (April 1992)

15. Multiple Roles for GIS in Global Change Research (1992)

16. Legal Issues (1993)

Because NCGIA is committed to basic and fundamental research, most of its research is as relevant to the international community as it is within the United States. Therefore, substantial areas of NCGIA's research agenda overlap with the five topics for a research programme and three axes scheduled for the Aix-en-Provence workshop. However, some issues appear to be of greater concern in the European context, due to the following factors:

- data must be shared across language and national boundaries, putting greater importance on all of the impediments to data sharing, particularly data description;
- quality is likely to be highly variable, suggesting the need for research into methods of visualizing and analyzing data with explicit quality descriptors;
- language differences will require attention to formal definitions and conceptual structures that do not depend on natural language for their meaning;
- data volumes may be very high; and
- high-speed networks and retrieval languages capable of supplying large volumes of data to individual scientists working in widely dispersed locations will be needed.

Suggestions for a European research agenda

In offering my suggestions for a European research agenda, I assume that GIS research needs to be directed towards making the technology more useful and successful in all of its applications. Because science plays a significant role among GIS applications, research to increase the value of GIS as a technology for science surely deserves particular attention. At the same time, research to improve the value of GIS for administration and information management also is important.

With this preamble, I propose the following topics as possible components of a European GIS research plan. In all of them, however, there are clear grounds for international cooperation and joint activities. The proposed topics also reflect my own personal biases, rather than those of the NCGIA.

Pattern recognition tools for earth science. To date, GIS technology has

been applied more for the analysis of existing data, than for the support of interpretation and information compilation in the earth sciences. Disciplines such as geology and geomorphology depend heavily on the ability of the field scientist to interpret data from many sources, and to compile a model of reality using a variety of sophisticated spatial concepts. A significant challenge for the GIS research community would be the development of a set of tools for such interpretation and compilation, either in two or three dimensions. Such tools have been applied to map scanning, but not as yet to compilation from multiple sources.

Improved approaches to map scanning. Data input is a costly bottleneck to GIS, because of the reliance on map digitizing. Scanning offers a cheaper alternative only if ways can be found to avoid the fundamental ambiguities of map documents. The Soviet work by E E Shiryaev, *Computers and the Representation of Geographical Data*, published in the United States by Wiley & Sons (1989), identified a series of techniques for enhancing the efficiency of scanning by minor design changes in maps, but has never been developed to proof-of-concept.

Data models for spatial information of variable quality. We have suitable error models for various kinds of geographic data, but need to begin implementing them by adopting data models in which quality is made explicit. Moreover, we have very little experience in describing data quality except through simple cartographic quality standards, which are of little value in GIS applications. A multinational European database project could be used as the vehicle for developing and demonstrating methods for incorporating quality information at all stages from data collection to analysis. Techniques being developed under NCGIA Initiative 7 could be used to show varying levels of uncertainty in map displays, and we also have methods for analyzing the propagation of uncertainty through various stages of analysis under certain conditions.

Analysis techniques for variable quality. Not strictly within the domain of the Aix-en-Provence workshop, but relevant to it, is the development of techniques to handle and analyze data of variable quality. Simple statistics like the mean can be weighted to reflect the inherent uncertainty in parts of the database.

The consequences of estimating means, based on unequal weights, need to be explored from a policy perspective. More generally, it is possible to imagine versions of all of our standard methods of spatial analysis where quality is allowed to vary across the input data.

Metadata. The key to sharing data of varying lineage and quality is clearly a system of effective documentation, and a method of communicating that documentation to the user. Metadata are of great interest in GIS at this time, and a number of efforts are under way to develop systems for metadata handling, standards for metadata, and standardized methods of description of parameters such as quality. US and European standards are likely to reflect the different priorities in each context, with a greater emphasis in Europe on language, quality and variation in origins. Research on metadata should include the development of indexes and catalogs for spatial data sets.

Networks. European research networks are likely to be more heterogeneous than those in the United States, but while problems of language and culture make the design of data networks for scientific purposes more challenging, they also make the eventual benefits more substantial. We must assume that a European geographical database will be distributed and delivered over some form of electronic network, and that both database and network must be designed accordingly.

NCGIA is delighted to be part of the planning process for a collaborative European GIS research effort and would like to help in any way it can. Our research agenda will certainly overlap any European GIS research program substantially, because although emphases and contexts may be different, most issues are fundamental to all geographical data. Europeans have played a significant and valuable role in many past NCGIA activities, and I hope we can continue to develop a spirit of cooperation for mutual benefit in the future.

Michael F Goodchild is the director of the National Center for Geographic Information and Analysis (NCGIA), University of California, Santa Barbara, CA 93106-4060, USA.

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