The Power Of GIS Extended To Scientific Researchers

The National Center for Geographic Information and Analysis is taking a leadership role in GIS research and education.

by Michael Goodchild and John Estes

The technologies and related databases to build a GIS were still comparatively inaccessible in the early 1980s, when Jerome Dobson, a geographer at Oak Ridge National Laboratories in Tennessee, concluded that a national center for GIS-related activities could provide an important contribution to development of this burgeoning field. A lack of standards and affordable peripherals would be a principal focus of the center, which would be funded by the National Science Foundation (NSF). It would dedicate itself to the development and transfer of affordable technology, and would provide a central database and GIS service over the communication lines then available.

The underlying parameters of GIS had changed dramatically by the time NSF issued a solicitation in 1987.

Personal computers and UNIX workstations had put more power on the desks of researchers than a 1980's minicomputer could have provided, at one-hundredth of the cost. Mature and powerful GIS software packages became readily available for a few thousand dollars, and large datasets could now be packaged on CD-ROM for tens of dollars per gigabyte. GIS teaching programs in a range of disciplines from geography to surveying and civil engineering had been established at the undergraduate and graduate levels, and research labs made GIS available as a supporting technology for a wide variety of activities.

It had become clear, however, that while the hardware, software and data needs of GIS users were better satisfied, there were decreasing supplies of intellectual capital, trained teaching staff, documentation of GIS core concepts and theories, and awareness of methods of analysis and decision-making. To an agency such as NSF, charged with supporting scientific research, the dominance of the GIS vendor industry by non-scientific applications—such as facilities management in utilities and local government—was increasingly worrisome. How could the power of GIS be made more available to scientific researchers?

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The solicitation for a National Center for Geographic Information and Analysis (NCGIA) envisioned a center that would be funded for five years at just over $1 million per year, although it would also be expected to generate substantial additional funding from other institutions. Eight bids were received, involving a total of 17 institutions, and in August of 1988, the center was awarded to a consortium led by the University of California, Santa Barbara, and including the State University of New York at Buffalo and the University of Maine. Competition for the center led to substantial exposure for GIS within the U.S. academic community, and many universities made significant investments in GIS at that time.

The primary mission of the center is to conduct "basic research on geographic analysis utilizing GIS." The four subsidiary goals are to:

- Advance the theory, methods and techniques of GIS
- Augment the nation's supply of experts in this field
- Promote GIS throughout the scientific community as an enabling technology for research
- Provide a central clearing house for information

The consortium agreed that the last goal could be met much more effectively if emphasis was put on intellectual information, such as bibliographies, software and the development of common research agendas, since several agencies already had responsibility for distributing digital geographic data.

Five research areas were identified by NSF as potential topics for the center:

- Spatial analysis and spatial statistics—particularly the development of improved methods of analysis and the use of statistical methods to deal with uncertainty in spatial data
- Spatial relationships and database structures—based on comparisons between abstract digital representations of space and the processes of human cognition and reasoning about geographic information
- Artificial intelligence and expert systems, and the application of these techniques to GIS

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• Visualization of spatial data and the exploitation of the potential of electronic display to help the user analyze and understand geographic phenomena

• Social, economic and institutional issues, widely believed to be the most significant impediments to the effective use of GIS, but at the same time probably the most difficult to resolve.

The research plan included in the consortium's proposal found significant research issues in each of these areas, and proposed to tackle them using a standard format: the research initiative. This format focuses the attention of center researchers on specific topics in a multidisciplinary, multi-investigator framework. Every initiative follows the same basic structure, beginning with a specialist meeting which brings approximately 35 people together from the GIS community to discuss and lay out an appropriate research agenda. The center uses a variety of strategies to coordinate its research with what is going on in other groups and institutions, and the specialist meeting has been used as a way of building a community-wide consensus and research network in each area. After one to two years of research, the results of the initiatives are presented at a major conference.

Twelve initiatives were originally identified for the first three years of activity, and the list has since been modified and extended. Three initiatives are now complete, although research continues, particularly in new initiatives with related subject matter.

The first initiative focused on the uncertainty and error present in much spatial data and its effects on GIS processing. Error models were developed and applied to help understand the propagation of uncertainty from GIS input to output. Initiative 2 focused on the terms used by people to learn, understand and reason with spatial data, and on how the languages used by GIS might be made more compatible.

Initiative 3 studied the problem of multiple representation—the need to present the same information differently at different scales, and the duplication and redundancy it causes for many GIS databases.

Among the newer research areas, Initiative 7, which began in June of 1991, focuses on whether it is feasible to modify GIS displays to convey some notion of the uncertainty present in spatial data. This study leads directly out of the research already completed in Initiative 1. Similarly, Initiative 13 leads on from Initiative 2 to address the practical design of user interfaces, and the exploitation of metaphor, graphic icons and other techniques of modern interface design.

Two sharply contrasting bodies of opinion must be reconciled: that user interfaces should be simple and easy to use; and that simplicity and ease of use are fundamentally at odds with the complexity of spatial concepts and reasoning.

Initiative 14, to begin in April of 1992, will explore the ability of GIS to support a wide range of forms of spatial analysis, from simple intuitive exploration to complex confirmatory tests of statistical hypotheses.

Additional information on all of these research activities is available in the biannual NCGIA newsletter "Update," in publications from the center's technical papers series, and in numerous books and articles that have resulted from the work. Annual reports listing all center publications are also available.

For further information, write to the NCGIA, David Simmonett Center for Spatial Analysis, University of California, Santa Barbara CA 93106, or telephone 805/893-8224.

The consortium concluded early on, after much soul-searching, that the best way to augment the nation's supply of experts in GIS technology would be to provide a set of readily accessible, adaptable teaching materials. At that time, there was a serious lack of textbooks in GIS, and instructors faced a daunting task in creating a GIS course from scratch.

The NCGIA solution has now become known as the Core Curriculum project, and has developed into a set of teaching materials for three courses. They are taught at the University of California, Santa Barbara, in a one-year sequence in geography, and they can be adapted to fit the teaching timetables and needs of other institutions and disciplines. The materials include instructor course notes, exam and discussion questions, handouts, overheads and slides. Individual units are designed to be as independent as possible, and are grouped into modules of related units. The materials are intended to be adaptable, and to be used selectively with other material.

In the first stages of the Core Curriculum's development in late 1988, an outline of three courses including Introduction to GIS, Technical Issues in GIS, and Application Issues in GIS, was discussed. After many modifications, GIS leaders worldwide were invited to contribute material. The results were released as a test version in the summer of 1989. Over 100 sites received the test materials for use in their own courses. After the schools commented, the final version of the curriculum was released in late July of 1990.

By July of 1991, nearly 700 copies of the curriculum had been distributed. Approximately 60 percent went to educational institutions, with 42 percent of those going to departments of geography. There were 22 requests for copies of the curriculum from U.S. college surveying departments. Over 50 countries have now received copies. An international program has been instituted whereby the center sponsors translation and distribution from a central site in each country. A number of user group meetings and workshops have been held at national and international meetings, and an electronic discussion list has been started.

An education project the center is currently involved in deals with lab exercises, and with the need to provide students with challenging hands-on experience to supplement the instructional material of the core curriculum. A directory of lab materials will be available, and will include labs developed at the center for use with the core curriculum. The directory will also include references to materials made available by other institutions, as well as materials developed for practical university education programs by GIS vendors.

A significant contribution to increased GIS interaction is being played by elec-

tronic mail. Over a year ago the Buffalo site of NCGIA sponsored GIS-L, an electronic mail discussion list for GIS. It now has about 600 readers and contributors, and message traffic averages 20 per day. Discussion is lively, and not always particularly deep, but lists such as GIS-L allow daily international communications between scientists, users and developers that are largely independent of discipline, national boundaries, distance, and many of the traditional constraints on human interaction. Several instructors have recognized the value of GIS-L as a source of insight for their students into the concerns and opinions of the GIS community. It certainly demonstrates the fast-moving, international character of the GIS community.

The worldwide GIS research community has accumulated a vast amount of useful and significant results over the past two decades, and recent interest in GIS has been matched by an accelerated rate of activity, of which NCGIA represents only a small part. At the same time, major issues remain, and GIS seems to create as many problems as it resolves. In fact, GIS may be its own worst enemy in revealing inadequacies in data, errors and uncertainties, and the lack of effective methods of decision-making.

Two problems seem particularly worrisome. Reference was made earlier to the seriousness of social, institutional and managerial issues in impeding the success of GIS, and to the difficulty of tackling these impediments at the research level. Research to date has made it clear that there are no simple solutions to these problems, and that results are extraordinarily difficult to generalize. There is a distinct need for policy-oriented research, aimed at affecting the entire context within which GIS operates, rather than problem-oriented research aimed at the removal of specific impediments.

A second problem concerns the fact that GIS is a highly applied environment, in which basic research must somehow find a useful role to play in supporting a fast-moving software industry and dynamic user community. The motivation for basic research must often come directly from application, and the results must be transferred through close university-industrial cooperation if they are to be effective.

This is an environment in which center-based research can be much more effective than traditional, single-investigator research, because a center can support the infrastructure needed for effective communication. Centers can sponsor courses for industry, joint conferences, publications and electronic networks, all of which can help move research results into the applications domain. **PS**

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