Chapter 27

The US National Center for Geographic Information and Analysis: some comparisons with the Regional Research Laboratories

Michael F. Goodchild
NCGIA, University of California, Santa Barbara

David W. Rhind
Birkbeck College, London

The origins of the Center

UK readers will be familiar with the Regional Research Laboratories, set up in eight universities across the country and 'core funded' by the Economic and Social Research Council. The rationale underlying this £1.75 million, three year scheme was described by Masser in the *AGI Yearbook 1989* (pages 309–12); many also know of the £1 million additional research funding allocated competitively by NERC and ESRC in 1989 and being spent over the following three years. What is much less well known is the equivalent development in the USA – the National Center for Geographic Information and Analysis (or NCGIA). This article describes the setting up and the work of the NCGIA and points out how the two organisations differ substantially in certain respects.

In the USA, funding of basic (c.f. applied) science by government is mainly carried out by the National Science Foundation (NSF). This is roughly the equivalent of the five UK research councils which fund science and engineering, the natural environment, agriculture and food, medical and economic and social research. In 1987, NSF published a request for bids for a centre and this identified 'basic research on geographic analysis utilising GIS' as the primary mission of the proposed centre. Five areas were suggested as possible research topics: improved methods of spatial analysis and advances in spatial statistics; a general theory of spatial relationships and database structure; artificial intelligence and expert systems relevant to the development of geographic information systems; visualisation research pertaining to the display and use of spatial data; and social, economic, and institutional issues arising from the use of GIS technology. In addition to research, the centre was to take steps to 'augment the nation's supply of experts in GIS and geographic analysis in participating disciplines; promote the diffusion of analysis based on GIS throughout the scientific community; and provide a central clearinghouse for disseminating information regarding research, teaching and applications'.

The request for applications for the centre appeared in mid-1987 and attracted intense interest. GIS, though emerging as a significant industry, was not identified

clearly with any academic discipline and did not then have many of the usual symbols of academic respectability – journals, societies, textbooks, etc. NSF's willingness to commit major funding for basic GIS research seemed to give the field a new level of respectability in the USA, not only as a tool for management and mapping, but as a powerful technology for scientific analysis and research. Moreover, the funding was to be channelled through NSF's Geography and Regional Science Programme and Division of Social and Economic Science, unlike previous centres established in science and engineering. This reinforces belief in GIS as an 'enabling technology' for a wide range of sciences dealing with spatially distributed phenomena.

The evaluation of the bids to become the NCGIA resulted in the University of Wisconsin and a group formed by a triumvirate of the universities – the University of California at Santa Barbara, the University of Maine at Orono and the State University of New York at Buffalo – being short-listed. NSF's final choice was the latter and work began in earnest in August 1988.

The Center, then, is housed in two geography departments (Santa Barbara and Buffalo) and in a surveying engineering department (Maine). Michael Goodchild and David Simonett, Santa Barbara, are the co-directors; the three associate directors manage the site operations: Terence Smith in Santa Barbara, Ross Mackinnon in Buffalo, and Andrew Frank in Maine. The senior scientist is Waldo Tobler, member of the National Academy of Sciences and a father figure in computer mapping and quantitative geography. A board of directors, which meets in June and December, reviews all aspects of the Center's operation. The eighteen members, who are drawn from universities, industry, government agencies and professional societies, include three members of the National Academy of Sciences.

Research

The consortium proposed a research plan built around the concept of 'impediments'; that GIS technology had enormous potential, but that numerous road blocks needed to be overcome (a similar approach was taken in the Chorley report). Some obstacles are technical, such as the unfriendliness of many user interfaces; some are institutional, such as the lack of standards for digital geographical data; others are social and economic, including the difficulty of assessing costs and benefits of GIS, and lack of understanding of the impacts of GIS technology on organisations. Research at the Center is organised around the systematic removal of these impediments within the five areas suggested in the NSF document which invited bids for the Center. The full text of the research plan has been published in the *International Journal of Geographical Information Systems* (1987, **1**, pp. 303–326).

The research programme is structured as a series of initiatives, each one focusing on a single topic for a period of one to two years. An initiative begins with a specialist meeting, which brings together outside experts to plan the initiative's agenda. Typical meetings held in the first year have involved from 25 to 50 people from universities, government agencies and industry.

During the first year the centre began research initiatives in five areas.

(1) Accuracy of Spatial Databases

Many GIS users are aware of the problems that result from inaccuracies or errors in spatial data, and the way these propagate through GIS operations. More than 50

participants attended the specialist meeting for Initiative 1 in Santa Barbara in December 1988 and developed a research agenda that called for a bibliography and taxonomy of spatial data errors; improved models of error description and ways of incorporating these into databases; analysis of error propagation, particularly in the sophisticated models now being built on spatial databases; better understanding of the relationship of accuracy and choice of data models, particularly for topographic data; and the role of geography in the accuracy of social and economic data.

Research on these topics began shortly after the specialist meeting and is continuing. Results thus far include a book entitled *Accuracy of Spatial Databases* (edited by M.F. Goodchild and S. Gopal, published by Taylor & Francis, London) and various of the Center's technical papers.

(2) Language of Spatial Relations

There are considerable differences in the ways in which spatial data are structured and processed in GIS, and in the ways people learn and reason about spatial information. These gaps will have to be closed if user interfaces are to be improved substantially. Initiative 2, which is designed to contribute in this area and which held its specialist meeting in Santa Barbara in January 1989, is led by Andrew Frank (Maine) and David Mark (Buffalo). Research is well under way on the following topics: way-finding, driving directions and spatial knowledge acquisition; analysis of their structure and cross-cultural and cross-linguistic variation (with potential application to vehicle navigation aid systems); cross-linguistic analysis of locative expressions and studies of linguistic variation in natural language terms for spatial relations; user interface design, including research on multi-media interfaces, metaphors for conveying and perceiving spatial information, and the visualisation of spatial relations; and formalisation of spatial relationships, research on formal definitions, the algebra of spatial relations, and formal reasoning.

(3) Multiple Representations

Although the ability to change the scale of a display is one of the more immediately attractive features of a GIS, scale and spatial resolution are established clearly by such parameters as raster cell size or the scale of the input document. Complex rules of generalisation are needed to convert the representation of a simple feature like a coastline to a smaller scale, and it is extremely difficult to convert to a larger scale in an appropriate way. As a result, many databases must include multiple representations of the same geographical feature.

Initiative 3, led by Barbara Buttenfield in Buffalo, is therefore focused on multiple representations and had its specialist meeting in February 1989. This research is centred on hierarchical data structures, which store information about an object or spatially distributed phenomenon at a range of scales; rules to automate the generalisation process; systems for describing change of geometry with scale; and data structures that formalise the relationships of multiple representations. In co-operation with a number of federal agencies, the Center is developing a multi-agency, multi-scale database to be distributed as a standard for research work in this area. In April 1990, the centre co-sponsored a symposium entitled 'Towards a Rule Base for Map Generalisation' at Syracuse University.

(4) The Use and Value of Geographic Information

Initiative 4, led by Harlan Onsrud (Maine) and Hugh Calkins (Buffalo), is the first to address social, economic, and institutional issues raised by the adoption of GIS technology. At the specialist meeting held in May 1989, three research themes emerged that are being refined by the research team:

(i) *The taxonomy of geographic information and its uses*
What types of geographic information exist, and how do they relate to the variety of data models of spatial databases? Are certain types of geographic information more or less suitable for handling in spatial databases? What role does geographic information play in human activity, who uses it, and for what purposes?

(ii) *The value of geographic information*
It is essential that we be able to measure the benefits of geographic information in decision-making if we are to come to grips with the most problematic half of the GIS cost-benefit ratio.

(iii) *The diffusion of innovations*
What factors control the rate at which knowledge about GIS diffuses and the rate at which this new technology is adopted in organisations? If these factors are potential impediments to adoption, how can they be controlled or removed? It has been suggested by Wolman that diffusion of the Core Curriculum itself might be an appropriate research study (see below).

(5) Design and Implementation of Large Spatial Databases

In July 1989, two meetings were held on this research topic in Santa Barbara; a formal symposium attracted more than 150 participants and a smaller, more intensive, workshop developed the initiative's research agenda. Led by Terence Smith and Andrew Frank, this initiative is examining the technical problems which arise in handling the large spatial databases now being constructed, such as the US Geological Survey's digital cartographic database.

In addition, in March 1990, the Center held the specialist meeting for Initiative 6 on Spatial Decision Support Systems (SDSS) in Santa Barbara. Issues discussed included the relationship of SDSS and GIS, data structure and software requirements, the design of user interfaces, and the value of the SDSS approach in complex spatial decision making. Preparations are now in hand for the next five research initiatives.

Education

The rapid development of the GIS field in the last few years has led to an acute shortage of adequately trained staff at all levels, particularly in those areas that require a moderate level of technical skills combined with an understanding of GIS applications. This problem is identical in many countries.

The Center's major effort in education in 1989 was the Core Curriculum Project. This was designed to increase the availability of teaching materials in GIS quickly so that courses could be introduced in new institutions and disciplines. The curriculum offers a one-year sequence, which may be taken in different ways to suit different academic organisations, and comprises a total of 75 one-hour lectures. The courses include lectures that introduce GIS, and cover technical and application issues: they include laboratory exercises and illustrative materials. During the 1989–90 academic year, 74 institutions around the world agreed to evaluate and

test the materials by incorporating them into their courses. A large proportion are geography departments, but the test sites also include marine science, geology, anthropology, engineering and other disciplines. Based on instructor and student feed-back, a second, final version of the curriculum is scheduled for distribution in Summer 1990.

Other education projects which the Center would like to pursue in the future include short courses for core curriculum instructors; short courses in specialised topics (two such one-day workshops were developed in 1989 and presented at several conferences); a case-study course modelled on those offered in many business schools; and training courses for users of specific systems, emphasising analytic and modelling capabilities.

A comparison of US and UK approaches

The design aims of the US National Center were significantly different from those of its nearest counterparts in the UK – the ESRC's Regional Research Laboratories. Whilst there were significant numbers of scientific contacts between the people involved in both initiatives, the differences include the following factors.

- The UK initiative was set up as a regional one from the outset and one role of each RRL is to interact with the local community in one form or another. The US one is strictly national; the three widely separated sites are simply an accident of history, arising from a recognition of the complementary skills at each site and their joint submission to the NSF.
- There was and remains a much greater emphasis on basic research in the US Center; judgements of its programme and overall success are made by its Board and NSF as a whole largely on scientific criteria. In the UK, criteria for the RRL's success are the promotion of quantitative social science in government, commerce and industry (notably through applied research and collaborative work with users), education and 'outreach' generally, as well as publications of the results of basic research.
- The research programme of the NCGIA was *the* driving force; each site is involved in formal collaboration with other sites, each leading national initiatives of the national programme. The evolution of the national programme is discussed and planned as a whole. In the UK, the research carried out is largely the sum of that chosen (and approved by ESRC at the outset) by each individual RRL; inter-RRL collaboration is largely on a person-by-person basis despite attempts to promote such collaborative work on a *post-hoc* basis. It is interesting to note, for instance, that only three or four applications out of 140 for additional research funds under a subsequent ESRC/NERC GIS research funding exercise in 1989 came jointly from two or more RRLs.
- The timescales of the US initiative are potentially much longer; in principle, NCGIA may be funded for up to eight years, as compared with the three year maximum of the RRLs and other GIS research in the UK funded by research councils. This partly reflects the difference in emphasis on basic research but it has had major influence on how the RRLs have developed: most have seen the need to develop applications-type research to provide post-ESRC funding for staff.
- The involvement of the wider community, including geographers, surveyors and other related disciplines in other higher institution sites outside the NCGIA or RRLs and researchers in apparently unrelated disciplines, is a matter of concern for both initiatives. This is being tackled in different ways: in the US, this is being achieved through formal involvement of many individuals in national meetings and in teams working on individual initiatives. In the UK, pragmatism and local developments are the normal arrangement.

Common to both initiatives, however, is the recognition of the need for enhanced education and training. In the US the development of a 75 lecture set has already been highly significant; in the UK, the development and publication of a GIS curriculum, the holding of meetings to 'trickle down' knowledge and expertise and the development of 'networking' – even down to the school level – has been the preferred approach. In the UK, again the role of the AGI in sponsoring meetings and encouraging the diffusion of knowledge, via the mechanism of the RRLs and by other means, has been a significant one. No such simple multi-disciplinary umbrella organisation exists in the USA, although joint conferences of the American Congress of Surveying and Mapping, the American Society for Photogrammetry and Remote Sensing, the Association of American Geographers, AM/FM and the Urban and Regional Information Systems Association fulfill one of the AGI's remits for wider dissemination of knowledge. The NCGIA and the RRLs have played a promising role in each national conference run by these organisations.