Michael F. Goodchild

Reflections of a Past Editor

The journal was eighteen years old when I took over as editor in 1987, and showing signs of adult maturity. I had arrived at McMaster as a graduate student in geography in 1965, from an undergraduate background in physics, during the heady days of the quantitative revolution in geography, and my view of the discipline was formed in large part by the early texts on spatial analysis: Haggett (1966), Berry and Marble (1968), King (1969), and Haggett and Chorley (1969). The founding of the journal in 1969 was in many ways the crowning event of that period, which was followed almost immediately by the growth of interest in quantitative analysis and modeling of human spatial behavior, and mathematical modeling in various branches of physical geography. Later when the journal reached school age came Marxism, the critiques of scientific geography, and post-positivism, but by then it was firmly established as the mouthpiece of a small but productive community that appeared to be largely unconcerned with the broader methodological debates that drew the attention of many on the human side of the discipline.

I spent much of my time in the 1970s and early 1980s working on applications of spatial analysis—using methods of location-allocation to site convenience stores and fast food restaurants, developing long-term plans for school systems, or routing electrical transmission corridors. Much of this involved the use of complex software, and economies of scale led to large-scale packages that integrated many spatial analytic functions around a common database. The geographic information systems that became popular in the mid-1980s were a simple consequence of these scale economies, but they have come to have profound effects on the world of spatial analysis.

The methods of spatial analysis of Berry and Marble (1968) and their contemporaries were simple, designed to provide useful insights in return for a relatively small expenditure of analytic effort. Simple FORTRAN programs were helpful but not essential for fitting a Poisson distribution to quadrat counts, or a straight line to a scatterplot. Factor analysis was one of the first popular techniques that almost demanded digital computation because of the complex calculations needed to invert even a modest-sized covariance matrix, and the spate of interest in factorial ecology in the late 1960s was in part a consequence of the advent of widespread access to academic computing. By the 1970s, a flood of new and more complex techniques began to appear that took advantage of the

Michael F. Goodchild is professor of geography at the University of California, Santa Barbara, and Chair of the Executive Committee of the National Center for Geographic Information and Analysis.

Geographical Analysis, Vol. 31, No. 4 (October 1999) The Ohio State University

computer's ability to process large numbers of data, evaluate large numbers of alternative hypotheses, and search for various kinds of pattern. Computers also exposed the inherent naïveté of much earlier analysis—its dependence on arbitrarily defined spatial units, the distorting effects of unwarranted assumptions, and the biases of excessive data aggregation.

I've tried to reconstruct my own thinking about spatial analysis in 1987, based on the preceding and in part on a paper I wrote at that time on the theme of spatial analysis and GIS (Goodchild 1987):

- A great amount had been learned about the analysis of spatial data, and published in the pages of *GA* and other journals. Techniques had grown more complex, as the problems with simpler methods had been recognized, and as computers had made it possible to implement increasingly complex models and tests. In fields such as location-allocation there was clearly no limit to the number and complexity of models that could be formulated.
- Nevertheless, applications of these techniques were conspicuous by their absence. The world was not adopting spatial analysis for practical purposes, and analysts had failed to make themselves indispensible outside the academic world, and perhaps even within it. Most applications were the somewhat artificial ones devised by the developers of methods, and much of spatial analysis seemed to be technique in search of application. Journals like *GA* served a smaller and smaller audience.
- GIS was becoming popular among a much wider audience. Its inherent attraction might be the key to greater implementation, if software developers could be persuaded to implement more sophisticated methods of analysis. Already ESRI's ARC/INFO was providing capabilities in location-allocation to people who would never think of reading the academic literature, and yet had ready access to applications of practical importance.

1987 was also the year the National Science Foundation solicited proposals for a National Center for Geographic Information and Analysis, and I became part of the winning bid from 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. Among the five topics that NSF suggested as research themes for the center were two that in hindsight turned out to be particularly relevant to the previous discussion: spatial analysis and spatial statistics; and languages of spatial relations. The first was there because NSF shared the view that GIS could be a vehicle for implementation. But the importance of the second was not as obvious at the time.

In 1987 most GIS installations ran on the so-called super-minicomputers manufactured by DEC, Prime, and Data General, under proprietary operating systems. The IBM PC had appeared six years earlier, but was not yet powerful enough to satisfy the demands of GIS. But by 1991 this situation had changed dramatically: individual workstations running Unix and costing $15,000 could now accommodate ARC/INFO, and the price of GIS software had fallen proportionately. Today, of course, we run full-strength GIS software under Windows NT on PCs costing no more than $2,000. Hardware costs are no longer a barrier to GIS access for many users. Moreover, the www has made it possible for vendors to offer GIS services over the network, obviating the need for local software entirely. With a standard browser, on the order of 10^6 people per day now use the Dijkstra algorithm to solve shortest path problems on road networks to find the best route from somewhere to somewhere else, using free services. Much more complex services are available from specialized vendors such as ESRI, for users who need to implement routing algorithms for deliveries and similar applications.

The www may have solved the problem of implementation, by making it possble for a very large number of users to access the methods of spatial analysis eveloped two decades earlier. But it has raised a series of interesting research uestions. What exactly do users with no background in spatial analysis underand by such methods? Is that understanding available to children, and of what ges? Can the educational system prepare people better by introducing princiles of spatial analysis and spatial thinking, and at what ages? What are the limts to understanding, in areas such as location-allocation where models range rom simple to highly complex? What if applications require calibration, or specification of parameters: can a user with limited understanding of the principles of statistics be expected to provide them?

These questions are intimately related to the second topic of the NCGIA research agenda, on languages of spatial relations, and they have come to dominate much of the GIS research agenda over the past ten years. Indeed, one of the greatest challenges in GIS research at this time concerns accessibility: how can the services of a GIS be made accessible to the general public, or children, when those services involve complex models and methods of analysis? Or to put it another way, must the GIS that is used by the general public be less powerful than the software available to experts? Is it possible to achieve a smooth transition between the formalizations of the digital world and the intuitive reasoning of the human mind? Or to present one of the many counter-arguments, shouldn't spatial analysis remain the domain of experts with many years of education, just as one must be an expert to be a concert pianist? Questions like these have led to interest in human cognition, as an inherent and important part of the emerging field of geographic information science (see, for example, UCGIS 1996).

GIS and the www may have solved many of the technical problems of access to spatial analysis, though the cognitive questions of understanding remain. They also focus attention on abundant problems related to data. If no geographic data set can be a perfect replica of the reality it supposedly represents, how is knowledge of imperfection to be conveyed to the user? How accurate are the databases and shortest paths supplied free by www service providers, and what is the impact of imperfect data on solutions to complex problems? How does one specify a need for data, and search the Internet for sources that could satisfy the need? More and more attention in the GIS research community is being directed to such issues, which were largely unaddressed in the earlier era when methods of spatial analysis were developed on the assumption that perfect data would be available, probably compiled by the expert analyst at substantial expense and over an extended period of time. But the old model of a leisurely, project-based timetable for implementation no longer applies in a world that needs instantaneous solutions to problems (Goodchild and Longley 1999) and sees little effective demarcation between science and problem-solving (Laudan 1996).

In short, it seems to me that accessibility has emerged over the past two decades as the most important issue surrounding the subject matter of *GA*. It is the ultimate determinant of relevance, which in turn is the final arbiter of long-term success. It has dictated much of the recent research agenda in GIS, as people have explored techniques of visualization, exploratory spatial data analysis, spatial cognition, the design of user interfaces, and other related issues. The research agenda is much richer than it was in 1987, the community of users and implementers is much larger, and, of course, the challenges are as substantial as ever.

LITERATURE CITED

Berry, B. J. L., and D. F. Marble, eds. (1968). *Spatial Analysis: A Reader in Statistical Geography*. Englewood Cliffs, N.J.: Prentice-Hall.

Goodchild, M. F. (1987). "A Spatial Analytic Perspective on Geographical Information Systems." *International Journal of Geographical Information Systems* 1(4), 327–34.

Goodchild, M. F., and P. A. Longley (1999). "The Future of GIS and Spatial Analysis." In *Geographical Information Systems: Principles, Techniques, Applications, and Management*, vol. 1, edited by P. A. Longley, M. F. Goodchild, D. J. Maguire, and D. W. Rhind, pp. 567–80. New York: Wiley.

Haggett, P. (1966). *Locational Analysis in Human Geography*. London: Edward Arnold.

Haggett, P., and R. J. Chorley (1969). *Network Analysis in Geography*. London: Edward Arnold.

King, L. J. (1969). *Statistical Analysis in Geography*. Englewood Cliffs, N.J.: Prentice-Hall.

Laudan, L. (1996). *Beyond Positivism and Relativism: Theory, Method, and Evidence*. Boulder, Colo.: Westview Press.

University Consortium for Geographic Information Science (1996). "Research Priorities for Geographic Information Science." *Cartography and Geographic Information Systems* 23(3), 115–27.