Spatial Concepts in GIS and Design

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Recently there has been widespread interest in identifying the fundamental concepts of critical spatial thinking. Several factors seem to be driving this interest. First, the advent of Google Earth and other related sites is raising interest and awareness among the general public of the power of geospatial technologies, the abundance of data, and the relevance of both to everyday activities. This *democratization of GIS*, in the form of sophisticated but at the same time easy-to-use tools, begs the question of what every citizen needs to know to use them effectively, and to avoid making misinterpretations. Yet at the same time, and despite the vast amounts of attention given to number and language skills throughout the K–16 curriculum, almost no systematic attention is given to the development of similar skills in reasoning and inference from *spatial* information. Even geometry, which addresses fundamental spatial properties, appears to be losing ground to algebra across the mathematics curriculum.

Second, the growth of geospatial technologies is dwarfed by the rapid increase in the accessibility of imaging and video, in the form of games and entertainment. The current generation of students is far more attuned to visual methods of communication, which appear to have replaced text as the focus of increasing amounts of attention.

Third, in recent years the group of tools collectively referred to as GIS has become significantly easier to use. Pull-down menus and pointers have replaced the command line of old, allowing the GIS user to focus more on the meaning of data manipulation and less on the mechanics. GIS still has a reputation for being difficult to learn and use, but there is no doubt that the interface has improved dramatically, allowing greater opportunity for critical thinking.

Several lists have been published in an attempt to identify the atomic concepts of critical spatial thinking, and at UCSB we have recently been engaged in an effort to develop a compilation, with cross-references and other aids. Some are rigorously defined, particularly when they are derived from concepts in mathematics, while others are more conceptual. Familiarity with some concepts clearly develops early in childhood, while others are typically encountered only in specialized university courses. Thus one way to organize the set is along a scale of conceptual sophistication. Another is according to metrics of similarity, and hierarchical relationships can also be investigated. In the second phase of our project we intend to develop a number of such organizing methods, to allow the set, which currently numbers 99, to be searched, visualized, and navigated systematically.

One of the motivations for this work lies in its potential to drive a more intuitive, easier interface to GIS. Over the years the number of functions supported by GIS has grown, and today it is possible to assert that GIS software can perform virtually any recognized

manipulation on geospatial data. But organizing the user interface has proven to be a difficult challenge. ESRI's ArcGIS Toolbox had 510 functions in its 9.2 version, and many other functions were accessible through pull-down menus and extensions. Although these are grouped hierarchically, the grouping often makes little sense. A well-organized, logical list of spatial concepts, organized according to well-defined principles, could help enormously to make the tools of GIS easier to learn and use.

The concept lists were almost without exception devised by geographers, and some date from the earliest years of geography's so-called Quantitative Revolution in the 1960s, when there was a widespread effort to identify the fundamentals of a scientific approach to the discipline. That approach was grounded in a positivist philosophy, with the objective of discovering natural principles and laws about the geographic landscape, both social and physical. Ever since the 1960s there have been efforts to apply the knowledge discovered in this way for normative purposes, in other words to design improvements to the geographic landscape. This is very much the position of the subdiscipline known as applied geography; it explains the often tight relationship between geography and planning; it explains the interest that is expressed from time to time in a geographic form of engineering; and it underlies the development of spatial decision-support systems. In all of these cases attention shifts from how the world looks and works, to how it might be given various forms of intervention. Moves of this sort remain contentious in geography, however, as they do across many areas of science, because they appear to divert effort from the central mission of discovery.

Many areas of GIS are already devoted to design, however. The functions of location-allocation, vehicle routing and scheduling, logistics, and spatial decision support are all oriented to computing solutions or designs that optimize well-defined objectives. Yet many areas of design lie well outside the domain of GIS, and it is not uncommon to encounter hostility to information technology in some areas of design. Methods such as location-allocation that are highly formalized clearly adapt themselves readily to GIS, whereas information technology can appear to have little to offer to the more artistic, humanist, subjective areas that defy formalization.

But if a continuum exists between the objective and subjective extremes of design, where exactly should the limits of information technology be placed? As information technology becomes more versatile and easier to use, should the limits be moving to encompass a larger part of the continuum?

These questions can be addressed at various levels, and the participants in this specialist meeting have been chosen with that in mind. At the most basic level, we can ask about GIS technology, and about the functions that would have to be added or enhanced to place greater emphasis on design. These would include tools to support sketch and other kinds of intuitive input; and to support the analysis of such input against various criteria. The sketch/simulate sequence in which a user would first sketch a rough design, and then allow

the system to simulate and evaluate its impacts, seems particularly important, and suggests the need for a series of tools for simulating dynamic processes. Spatial decision-support systems have been discussed for many years, but we have yet to develop a set of reusable software components to support decision making in GIS, and fundamental research is still needed to identify those components.

At the conceptual level, one would pose the question very differently: What are the fundamental concepts of design, and how are they related to the spatial concepts identified as fundamental by geographers? For example, if spatial dependence in the form of Tobler's First Law—nearby things are more related than distant things—is a general and fundamental principle of geography, what is its meaning in design? Are there spatial concepts in design that need to be added to the 99 in the UCSB list?