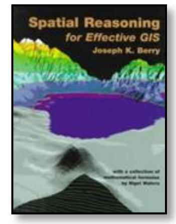
Beyond Mapping II



***Spatial Reasoning* book**

Introduction

Is the GIS Cart in Front of the Horse? — *discusses driving forces, trends and forecasts in contemporary GIS from the perspective of modeling interrelationships among mapped variables*

Explore a New Spatial Paradigm — *discusses the movement from mapping and spatial inventories by technologists to spatial reasoning and dialog involving enlightened users in development of solutions to complex spatial problems*

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Is the GIS Cart in Front of the Horse?

(GeoWorld, July 1996)

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What began in the 1960s as a cartographer's tool has evolved into a revolution in many disciplines. General users have become more directly engaged with GIS technology, radically changing the nature of GIS applications. Early uses emphasized mapping and spatial database management. Increasingly, applications have moved to modeling the interrelationships among mapped variables. Most of these applications have involved cartographic modeling, which employs GIS operations to mimic manual map processing techniques, such as map reclassification, overlay, and simple buffering around features. The new wave of applications concentrates on spatial modeling, employing spatial statistics and advanced analytical operations. The spatial modeling approaches can be grouped into three broad categories: data mining, predictive modeling, and dynamic simulation.

Data mining uses the GIS to discover relationships among mapped variables. For example, a map of dead and dying spruce/fir timber stands can be statistically compared to maps of driving variables, such as elevation, slope, aspect, soil, and depth to bedrock. If a strong spatial coincidence (correlation) is identified for a certain combination of driving variables, that information can be used to direct management action. In the sickly tree example, if the dead trees tend to be on high, steep, northern slopes with thin, acid soils, then forest managers can ask the GIS to identify areas of trees living in these conditions and take appropriate preemptive action. It's like the remark made by famous robber Willy Sutton when asked why he robbed banks: "That's where the money is." Often the simple relationships hidden in complex data are revealed by a slightly different perspective.

Another form of data mining is the derivation of empirical models. For example, a geographic distribution (3-D surface) of PCB concentrations in an aquifer can be interpolated from water samples taken at several wells. Areas of unusually high concentrations (more than one standard deviation above the average) are isolated. When a time series of the high-concentration maps is animated, the contamination appears to move through the aquifer-hence, an empirical ground water model. A "blob" moving across the map indicates an event, whereas a steady "stream" snaking its way along indicates a continuous discharge of a Pollutant.

Most predictive modeling is nonspatial. Data are collected by sampling large areas, then reducing the set of measurements to a single typical value (arithmetic average). The average values for several variables are used to solve a mathematical model, such as a regression equation. For example, a prediction equation for the amount of breakage during timber harvesting is defined in terms of percent slope, tree diameter, tree height, tree volume, and percent defect, with big, old, rotten trees on steep slopes having the most breakage. The nonspatial approach ignores the inherent spatial information collected and substitutes the average of each variable into the equation to solve for a single estimate of breakage for an entire area. A GIS solution, however, spatially interpolates the field data into mapped variables, then solves the equation for all locations in space. That approach generates a map of predicted breakage with "pockets" of unusual breakage levels clearly identified. Analogous procedures can detect pockets of unusually high sales of a product, levels of crop productivity, or incidence of disease.

Dynamic simulation allows the user to interact with a spatial model. Model behavior can be investigated by systematically changing the model's parameters and tracking the results. This "sensitivity analysis" identifies the relative importance of each mapped variable within the context of its unique geographic setting. In the timber breakage example, the equation itself may be extremely sensitive to steep slopes. In a project area with only gentle slopes of less than l0 percent, however, tree height might be identified as the most important factor.

A less disciplined use of dynamic simulation enables a GIS to act like a spatial spreadsheet and address "what if" questions. For example, the avoidance of steep slopes and visual connectivity to houses might be considered in a highway siting model. What if steep slopes are considered more important? Where does the proposed route change, and where does it not change? What if visual connectivity is considered more important? This informal use of dynamic simulation actively involves decision makers and interested parties in the map analysis process. The induced dialogue develops a common understanding that greatly exceeds the information packed in a static data sandwich of maps.

What is the reality of these futuristic tools? In many respects, the new applications might have "the cart in front of the horse." GIS can store tremendous volumes of descriptive data and overlay myriad maps for their coincidence. It has powerful tools for expressing the spatial interactions among mapped variables. There is, however, a chasm between GIS and applied science. The reality is that the bulk of our scientific knowledge lacks the spatial specificity in the relationships among variables demanded by these advanced applications. We have a tool that characterizes spatial relationships (cart); we lack the research and understanding of its expression in complex systems (horse).

For example, a GIS can characterize the change in a relative amount of edge in a landscape by computing a set of fractal dimension maps as a forest is modified. That and more than twenty other landscape analysis indices allow us to track landscape dynamics, but what changes in the indices mean for nesting birds is beyond our current scientific knowledge. similarly, a GIS can characterize the effective sediment-loading distance from streams as a function of slope, vegetative cover, and soil type. It is common sense that areas with stable soil on gentle, densely vegetated intervening slopes are farther away from a stream (in terms of sediment-loading potential) than areas with unstable soils and steep, sparsely vegetated intervening slopes.

But how are effective sediment-loading distances translated into fish survival? Exactly where can a developer dig up the dirt and not have the dirt balls rain down on the fish? Similarly, neighborhood variability statistics allow us to track the diversity, interspersion and juxtaposition of vegetative cover types. How then are these statistics translated into management decisions about wildlife populations? Exactly where can a logger cut trees without destroying the last spotted owl? These (and many others) are serious questions that can't be solved by technology or science alone.

The ability of GIS to integrate multiple phenomena is well-established. The functionality needed to relate the spatial relationships among mapped variables is in place. What is lacking is the scientific knowledge to exploit these capabilities. Until recently, GIS was thought of solely as a manager's technology focused on inventory and record-keeping. Even the early scientific applications merely used it as an electronic planimeter to aggregate data over large areas for input into traditional, nonspatial models. I hope we are embarking on an era of scientific research in which spatial analysis plays an integral part and expresses its results in GIS modeling terms. The opportunity to have the scientific and managerial communities use the same technology is unprecedented. Until then, however, foresighted yet frustrated managers will be forced to use the analytical power of GIS to construct their own models— based on their common (and occasionally uncommon) sense.

Explore a New Spatial Paradigm

(GeoWorld, April 1995)

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Wha'cha mean a pair-o-dimes …heck, I don't even have two nickels to rub together.

The mechanics of GIS were made a lot easier in the last decade, but the relationships and assumptions built into GIS models remain mere sketches of uncharted intellectual terrain. Such is the challenge GIS presents to basic and applied science.

But what about the rest of us? Aren't the scientists going to do it all, leaving us to merely click on the right icon? What does the evolving technology have in store for the general user? In short, it offers a mind-expanding (or quite possibly, mind-exploding) paradigm shift in how we perceive, handle and employ maps. We are shifting from a product-focus to a utility-focus in our map dealings. No longer is it what a map contains, but how "that map combined with this map and eye of newt can produce what we really need." That takes us beyond mapping to *spatial reasoning*, meaning that the process and procedures of manipulating maps transcend the mechanics of GIS interaction. The ability to think spatially becomes as important as "how do I do that?"

Most GIS users have cognitive skills reflecting their experiences (both good and bad) with manual map processing and procedures. Their data analysis experience has been with nonspatial data, or measurements in which the spatial component was removed surgically, leaving only an average value. But GIS offers a host of new tools for analyzing mapped data. It follows that these new tools will spawn a new way of doing business with maps, beyond the vocational mastery of a system's user interface.

Cornerstone to this new perspective is an appreciation that maps are data-numbers first, pictures later. That is a radical departure from our 8,000-year history of mapping. In the past, maps primarily were *descriptive*. They showed the precise placement of physical features, usually for navigation purposes. Increasingly, maps have become *prescriptive*, serving as data in determining appropriate management actions. They tell us where it is (inventory), and they provide insight into how it could be (analysis).

Map analysis is an emerging discipline, recognizing fundamental map analysis operations independent of specific applications. These analytical tools extend mapping and management of spatial data to GIS modeling, expressing relationships within and among mapped data. Familiarity with this map analysis toolbox is the initial step toward spatial reasoning. Bizarre concepts, such as a Standard Normal Variable surface or Coefficient of Variation map, must become second nature before you can maneuver your souped-up GIS like a race car driver.

Spatial reasoning is the effective application of these tools to solve problems. That involves developing an understanding of their appropriate use for particular applications. Conceptualization of an elk habitat model, for example, requires an understanding of the important factors (mapped variables) and how to express their interaction (tools) to identify areas of suitable habitat (GIS solution). The GIS specialist, wildlife biologist and natural resource manager must work closely at the onset of model development. The problem can't be dissected into separate pieces and solved independently. Their collective strength lies in the ability to communicate various perspectives of the problem and its comprehensive solution. Because elk habitat is inherently a spatial problem, spatial reasoning becomes the medium of intellectual exchange.

As the civil rights adage says, "…the people with the problems are the people with the solutions." Thus, the GIS user must be involved in developing GIS solutions. You can't abdicate the responsibility of GIS model development to someone who just happens to know how to boot-up the GIS black box. Nor can you abandon the years of indigenous knowledge about the unique character of your area to a scientist in another region. Your obligations extend even beyond spatial reasoning skills to *spatial dialog* deftness.

During that final step, GIS is used as a decision support system. The focus is on consensus building and conflict resolution among interested parties. The GIS is used as a means to respond to a series of “what if” scenarios in which any single map solution isn’t important. It is how maps change as different perspectives are tried that develops enough information to support a decision. That process includes an understanding of the sensitivities involved in the decision. It also involves decision makers in the analysis process instead of just choosing among a set of tacit decisions (static alternatives) produced by detached analysis. Using GIS in this manner is a radical departure from current spatial reasoning and dialog methodologies. When you reach this plateau, you and your high-powered GIS are ready for the races.

One more point needs to be made. GIS is moving rapidly from the domain of the GIS specialist to the general user, and is about to face the utilitarian user who lacks the sentimental attachment of the earlier GIS zealots. In the past, end users were content with automating existing manual processing and data retrieval systems. As they become more knowledgeable and adept in map analysis and modeling, we can expect increasing demands on GIS that will push at the envelope of traditional concepts of map content, structure and use. Maps will be viewed less as descriptive images and more as mapped data expressing user understanding of spatial interactions. Effective communication of the spatial reasoning that supports modeled maps will become as important as statements of map scale and projection.

What a change of events. The technologists’ have been pushing GIS for years-both its virtues and products. We are at a point in time when things are about to reverse, and that may be the technologists worst nightmare. Instead of a small, friendly user community gratefully accepting the bug fixes and new features in each software update, there is a growing community tugging at the existing set of GIS capabilities and applications. The growing cadre of enlightened users is pushing GIS into new areas the technologists never dreamed of. But it's the only way to get your nickel’s worth out of GIS ...maybe even a new pair of dimes.

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