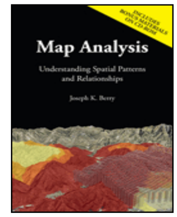
Epilog – *The Many Faces of GIS (Further Reading)*



Map Analysis book

<*Click here*> *for a printer-friendly version of this topic (.pdf).*

(*Back to the Table of Contents*)

Is GIS Technology Ahead of Science?

(GeoWorld, February 1999)

(*return to top of Topic*)

The movement from mapping to map analysis marks a turning point in the collection and processing of geographic data. It changes our perspective from "spatially-aggregated" descriptions and images of an area to "site-specific" evaluation of the relationships among mapped variables. The extension of the basic map elements from points, lines and areas to map surfaces and the quantitative treatment of these data has fueled the transition. However, this new perspective challenges the conceptual differences between spatial and non-spatial data, their analysis and scientific foundation.

For many it appears to propagate as many questions as it seems to answer. I recently had the opportunity to reflect on the changes in spatial technology and its impact on science for a presentation* before a group of scientists. Five foundation-shaking questions emerged.

Is the "scientific method" relevant in the data-rich age of knowledge engineering?

The first step in the scientific method is the statement of a hypothesis. It reflects a "possible" relationship or new understanding of a phenomenon. Once a hypothesis is established, a methodology for testing it is developed. The data needed for evaluation is collected and analyzed and, as a result, the hypothesis is accepted or rejected. Each completion of the process contributes to the body of science, stimulates new hypotheses, and furthers knowledge.

The scientific method has served science well. Above all else, it is efficient in a data-constrained environment. However, technology has radically changed the nature of that environment. A spatial database is composed of thousands upon thousands of spatially registered locations relating a diverse set of variables.

In this data-rich environment, the focus of the scientific method shifts from efficiency in data collection and analysis to the derivation of alternative hypotheses. Hypothesis building results from "mining" the data under various spatial, temporal and thematic partitions. The radical change is that the data collection and initial analysis steps precede the hypothesis statement— in effect, turning the traditional scientific method on its head.

Is the "random thing" pertinent in deriving mapped data

A cornerstone of traditional data analysis is randomness. In data collection it seeks to minimize the effects of spatial autocorrelation and dependence among variables. Historically, a scientist could measure only a few plots and randomness was needed to provide an unbiased sample for estimating the typical state of a variable (i.e., *average* and *standard deviation*).

For questions of central tendency, randomness is essential as it supports the basic assumptions about analyzing data in numeric space, devoid of "unexplained" spatial interactions. However, in geographic space, randomness rarely exists and spatial relationships are fundamental to site-specific management and research.

Adherence to the "random thing" runs counter to continuous spatial expression of variables. This is particularly true in sampling design. While efficiently establishing the central tendency, random sampling often fails to consistently exam the spatial pattern of variations. An underlying systematic sampling design, such as systematic unaligned (see GIS World, Beyond Mapping columns February-April, 1997), is better at insuring an even distribution of samples over an area of interest.

Are geographic distributions a natural extension of numerical distributions?

To characterize a variable in numeric space, density functions, such as the standard normal curve, are used. They translate the pattern of discrete measurements along a "number line" into a continuous numeric distribution. Statistics describing the functional form of the distribution determine the central tendency of the variable and ultimately its probability of occurrence. Consideration of additional variables results in an N-dimensional numerical distribution visualized as a series of scatterplots.

The geographic distribution of a variable can be derived from discrete sample points positioned in geographic space. Map generalization and spatial interpolation techniques can be used to form a continuous distribution, in a manner analogous to deriving a numeric distribution (see GIS World, Beyond Mapping columns May-August, 1998). In effect, the Gaussian, Poisson and binomial density functions used in non-spatial statistics are akin to the polynomial, inverse-distance-squared and Kriging density functions used in spatial statistics.

Although the conceptual approaches are closely aligned, the information contained in numeric and geographic distributions is different. Whereas numeric distributions provide insight into the central tendency of a variable, geographic distributions provide information about the geographic pattern of variations. Generally speaking, non-spatial characterization supports a "spatially-aggregated" perspective, while spatial characterization supports "site-specific" analysis. It can be argued that research using non-spatial techniques provides minimal guidance for site-specific management— in fact, it might be even dysfunctional.

Can spatial dependencies be modeled?

Non-spatial modeling, such as linear regressions derived from a set of sample points, assumes spatially independent data and seeks to implement the "best overall" action everywhere. Site-specific management, on the other hand, assumes spatially dependent data and seeks to evaluate "IF <*spatial condition*> THEN <*spatial action*>" rules for the specific conditions throughout a management area. Although the underlying philosophies of the two approaches are at odds, the "mechanics" of their expression spring from the same roots.

Within a traditional mathematical context, each map represents a "variable," each spatial unit represents a "case" and the value at that location represents a "measurement." In a sense, the map locations can be conceptualized as a bunch of sample plots— it is just that sample plots are everywhere (vis. cells in a gridded map surface). The result is a data structure that tracks spatial autocorrelation and spatial dependency. The structure can be conceptualized as a stack of maps with a vertical pin spearing a sequence of values defining each variable for that location— sort of a data shish kebab. Regression, rule induction or a similar techniques, can be applied to the data to derive a spatially dependent model of the relationship among the mapped variables.

Admittedly, imprecise, inaccurate or poorly modeled surfaces, can incorrectly track the spatial relationships. But, given good data, the "map-*ematical*" approach has the capability of modeling the spatial character inherent in the data. What is needed is a concerted effort by the scientific community to identify guidelines for spatial modeling and develop techniques for assessing the accuracy of mapped data and the results of its analysis.

How can "site-specific" analysis contribute to the scientific body of knowledge?

Traditionally research has focused on intensive investigations comprised of a limited number of samples. These studies are well designed and executed by researchers who are close to the data. As a result, the science performed is both rigorous and professional. However, it is extremely tedious and limited in both time and space. The findings might accurately reflect relationships for the experimental plots during the study period, but offer minimal information for a land manager 70 miles away under different conditions, such as biological agents, soil, terrain and climate.

Land managers, on the other hand, supervise large tracks of land for long periods of time, but are generally unaccustomed to administering scientific projects. As a result, general operations and scientific studies have been viewed as different beasts. Scientists and managers each do their own thing and a somewhat nebulous step of “technology transfer” hopefully links the two.

Within today’s data-rich environment, things appear to be changing. Managers now have access to databases and analysis capabilities far beyond those of scientists just a few years ago. Also, their data extends over a spectrum of conditions that can’t be matched by traditional experimental plots. But often overlooked is the reality that these operational data sets form the scientific fodder needed to build the spatial relationships demanded by site-specific management.

Spatial technology has changed forever land management operations— now it is destined to change research. A close alliance between researchers and managers is the key. Without it, constrained research (viz. esoteric) mismatches the needs of evolving technology, and heuristic (viz. unscientific) rules-of-thumb are substituted. Although mapping and “free association” geo-query clearly stimulates thinking, it rarely contains the rigor needed to materially advance scientific knowledge. Under these conditions a data-rich environment can be an information-poor substitute for good science.

So where do we go from here?

In the new world of spatial technology the land manager has the comprehensive database and the researcher has the methodology for its analysis— both are key factors in successfully unlocking the relationships needed for site-specific management. In a sense, technology is ahead of science, sort of the cart before the horse. A GIS can map spatial patterns and reactions to a meter (*technological cart*), but our historical science base has been calibrated by non-spatial analysis (*scientific horse*). The need for a partnership between managers and scientists has never been more acute; nor has it been so obtainable. For the first time managers and scientists share the same set of tools and an increasingly convergent perspective.

…***Technological Cart*** *in front of the* ***Scientific Horse****?*

<u>Author’s Note</u>*: This column is based on a keynote address for the Site-Specific*

Management of Wheat Conference, Denver, Colorado, March 4-5, 1998; a copy of the full text is online at www.innovativegis.com/basis, select Presentations & Papers.

Observe the Evolving GIS Mindset

(GeoWorld, July 2011)

(*return to top of Topic*)

A couple of seemingly ordinary events got me thinking about the evolution of GIS. It's obvious that technical advances, particularly in GPS and desktop mapping, have profoundly changed how we collect, process and interact with spatial data. However, changes in the community and mindset of GIS'ers are less obvious, yet might prove to be even more dramatic.

I recently attended an open house for a local GIS company that had outgrown its start-up digs. Two things had a significant impact on me— I hardly knew anyone and the conversations almost exclusively focused on data collection, storage and display (aside from the obligatory weather, sports and Bill/Monica discussions). The GIS community has grown (that's for certain) and the diversity of participants is a major factor accompanying its evolution. Whereas a few years ago, I would have known everyone at a GIS function (Fort Collins is still a pretty small town), the select set of "insiders" has been augmented (replaced?) by hordes of GIS users.

The expanded community has brought a refreshing sense of practicality and realism. The days of "GIS-ing for GIS sake," basic research and focus on general tools have given way to application-specific needs and constraints. A decade ago, "proof-of-concept" projects ruled and given a year and a topographic sheet-sized area, anything was possible. Today, operational systems are the focus and trickle-sized data sets have grown into an insatiable torrent of data flows. With the conversion of paper maps, resurrection of remote sensing data sources, GPS-linked data collection, geo-coded addressing of traditionally non-spatial data, and the accessibility of all these data over the Internet, GIS has more of a database technology character than that of a mapping science. The old adage that "a picture is worth a thousand words" has quickly become "an image is composed of millions of records." However, the full worth of a GIS image, in many cases, has yet to be determined.

That brings up the other event that got me thinking. It was an email that posed an interesting question…

> *"We are trying to solve a problem in land use design using a raster-based GIS (ESRI ArcView Spatial Analyst) to no avail. It has to do with the conflict resolution step of the problem. In this step, multiple raster layers are overlaid to produce an output grid depicting the most suitable land use based on where the maximum value was found. Hopefully the attached (see figure 1) should render our problem transparently clear."*

The problem involves "map-*ematical* reasoning" since there isn't a button called "identify the most suitable land use" in any of the GIS systems I know. Note that each of the grid cells in the maps (Residential, Golf Course and Conservation) contains a value identifying its relative suitability (higher value indicates more suitable). A human would simply determine the highest value for each grid location, note its data layer and color the cell appropriately (e.g., top-left cell would be 76, Residential, red; bottom-right cell would be 87, Conservation, green).

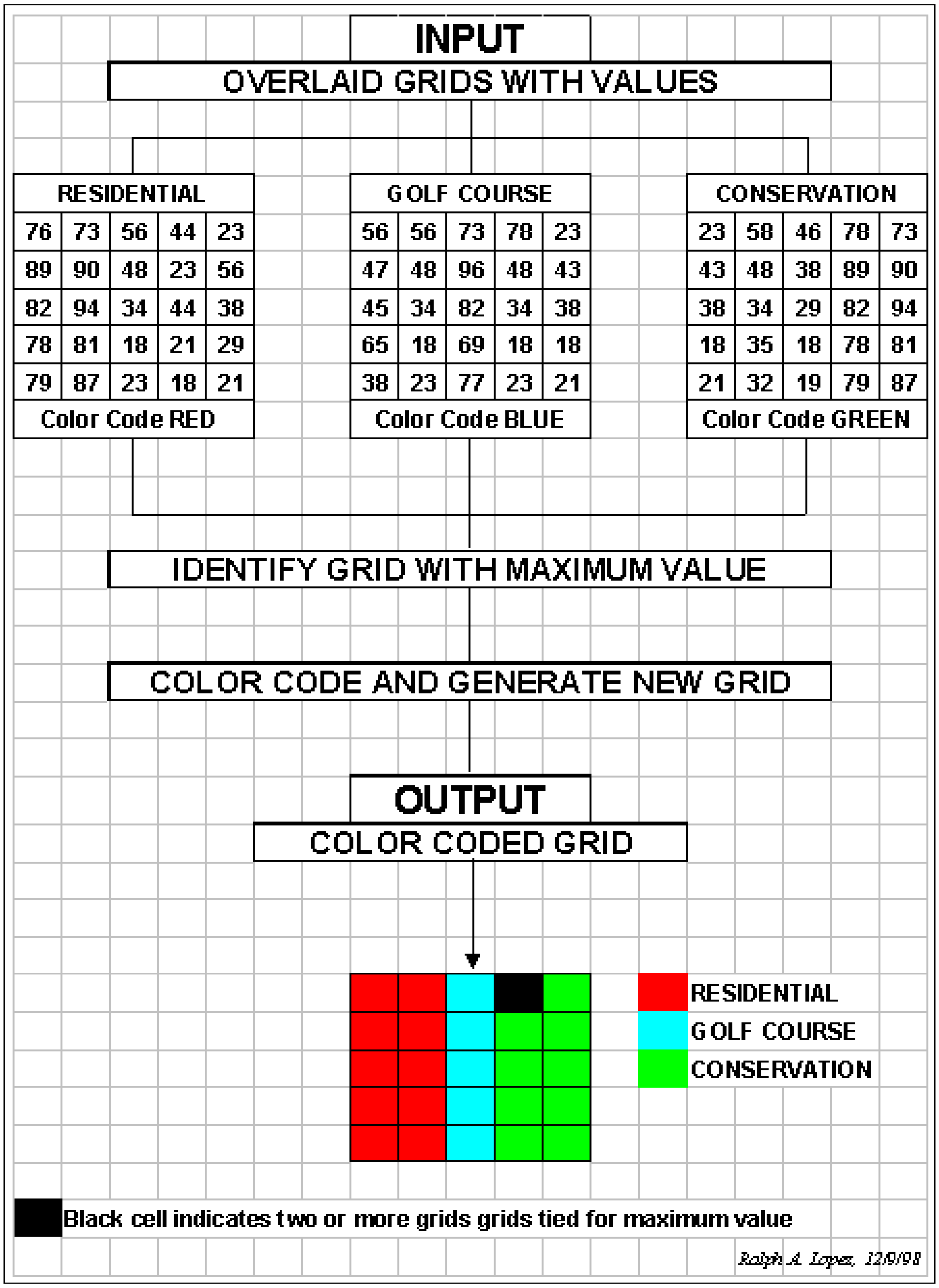


Figure 1. Schematic of the problem to identify the most suitable land use for each location from a set of grid layers.

That's simple for you, but computers and GIS systems don't have the same logical reasoning skills and have to slog-around, ankle-deep in the numbers. For example, one solution (there's others) might be expressed as…

***Step 1*. Find the maximum value at each grid location on the set of input maps**—

COMPUTE Residential_Map maximum Golf_Map maximum Conservation_Map for Max_Value_Map

***Step 2*. Compute the difference between an input map and the Max_Value_Map—**

COMPUTE Residential_Map minus Max_Value_Map for Residential_Difference_Map

***Step 3*. Reclassify the difference map to isolate locations where the input map value is equal to the maximum value of the map set (renumber maps using a binary progression; 1, 2, 4, 8, 16, etc.)**—

RENUMBER Residential_Difference_Map for Residential_Max1_Map
    assigning 0 to -10000 thru -1   *(any negative number; residential less than max_value)*
    assigning 1 to 0   *(residential value equals max_value)*

***Step 4*. Repeat steps 2-3 for the other input maps**—

… Golf_Max2_Map *using 2 and* Conservation_Max4_Map *using 4 to identify areas of maximum suitability for each grid layer*

***Step 5*. Combine individual "maximum" maps and label the "solution" map**—

COMPUTE Residential_Max1_Map plus Golf_max2_Map plus Conservation_Max4_Map
    for Suitable_Landuse_Map

LABLE Suitable_Landuse_Map

1 Residential	*(1 + 0 + 0)*
2 Golf Course	*(0 + 2 + 0)*
4 Conservation	*(0 + 0 + 4)*
3 Residential and Golf Course Tie	*(1 + 2 + 0)*
5 Residential and Conservation Tie	*(1 + 0 + 4)*
6 Golf Course and Conservation Tie	*(0 + 2 + 4)*
7 Residential, Golf Course and Conservation Tie	*(1 + 2 + 4)*

Note: the sum of a binary progression of numbers assigns a unique value to all possible combinations.

OK, how many of you map-*ematically* reasoned the above solution, or something like it? Or thought of extensions, like a procedure that would identify exactly "how suitable" the most suitable land use is (info is locked in the Max_Value_Map; 76 for the top-left cell and 87 for the bottom right cell). Or generating a map that indicates how much more suitable the maximum land use is for each cell (the info is locked in the individual Difference_Maps; 56-76= -20 for

Golf as the runner up in the top-left cell). Or thought of how you might derive a map that indicates how variable the land use suitabilities are for each location (info is locked in the input maps; calculate the coefficient of variation [[stdev/mean]*100] for each grid cell).

This brings me back to the original discussion. It's true that the rapid growth of GIS has greatly extended the community of users and certainly made terra-bytes of spatial data a mouse-click away. It has democratized the technology and brought practicality and realism into the equation. In effect, the evolution has made the spatial technologies (GIS, GPS and remote sensing) household terms and a near necessity in the modern workplace.

However, in many instances the focus has shifted from the analysis-centric perspective of the original "insiders" to a data-centric one shared by a diverse set of users. As a result, the bulk of current applications involve spatially-aggregated thematic mapping and geo-query verses the site-specific models of the previous era. This is good, as finally, the stage is set for a quantum leap in the application of GIS. We have data, we have users, and we have tools. What remains is a pervasive awareness of spatial reasoning— a new way of thinking with maps. The next epoch of the GIS evolution will change the GIS mindset as much as the previous ones have changed our tools and data sets.

Where Is GIS Education

(GeoWorld, June 1997)

(return to top of Topic)

GIS means different things to different people. To some, it is a tool that extends mapping to the masses. It allows the construction of custom maps from any desktop. It enables the spatially challenged to electronically locate themselves on a map, request the optimal path to their next destination, as well as checking the prices of motels along the way.

When coupled with a cell phone, they can call for help and their rescuers will triangulate on the signal and deliver a gallon of gas and an extra large pizza within the hour. Whether you are a lost explorer near the edge of the earth or soul-searching on your Harley, finding yourself has never been easier—the revolution of the digital map is firmly in place.

A new-age real estate agent can search the local multiple listing for suitable houses, then electronically "post" them to a map of the city. A few more mouse-clicks allows a prospective buyer to take a video tour of the homes and, through a GPS-linked handy-cam movie, take a drive around the neighborhood. A quick geo-query of the spatially-linked database, locates neighboring shopping centers, churches, schools and parks. The city's zoning map, land use plan and proposed developments can be superimposed for a glimpse of future impacts. Demographic summaries by census tracts can be generated and financial information for "comparables" can be plotted and cross-linked for a better understanding market dynamics. Armed with this information narrowing the housing choices, a prospective buyer can "hit the ground running" right off the airplane—the revolution of spatial database management is here.

However, the "intellectual glue" supporting such Orwellian mapping and management applications of GIS technology is still being fought in series of small skirmishes on campuses throughout the world. In part, the battles reflect the distribution of costs and benefits of the new discipline. From one perspective, GIS is viewed as a money pit draining the life-blood of traditional programs. It appears as an insatiable beast (like the plant's constant cry of "MORE!" in the Little Shop of Horrors) devouring whole computer labs with its gigabyte appetite and top-end taste in peripherals. The previous assault on "real computing" by the demeaning distractions of word processing, spreadsheets, and graphics packages pales by comparison. The insertion of yet another "techno-science" addition to the already burgeoning curricula appears to be the last straw. GIS's insidious tentacles are tugging at every department.

The classical administrator's response is to stifle the profusion of autonomous GIS labs and centralize them into a single "center of excellence." On the surface, this idea is not without merit. Its obvious economies of scale and orderly confines, however, often are met head-on by the savage realities of academic ownership. A GIS oversight committee composed of faculty from across campus often is an organizational oddity in a sea of established departments and colleges. Strong leadership within the committee is viewed as a "power-play" by the activist for his or her department and is quickly countered with the sub-committee kiss of death.

Keep in mind the old adage that "the fighting at universities is so fierce, because the stakes are so small." Acquisition of space and equipment are viewed less as a communal good, as they are viewed as one department's evil triumph over the others. My nine years as an associate dean hasn't embittered me, as much as it has ingrained organizational realities. Bruises and scar tissue suggest that the efficiencies and cost savings of a centralized approach to GIS (be it academic or corporate) are largely lost to organizational entropy, user detachment and a lack of perceived ownership.

As with other aspects of campus life, GIS technology might benefit more from its diversity than from its oneness, with a single academic expression sized to fit all. If GIS is to become a fabric of society and spatial reasoning a matter of fact, its tangible expression as a divorced edifice on the other side of campus is dysfunctional. To be embraced and incorporated into existing courses, it needs to be as close to its users' hearts and minds as the door across the hall. An intellectual osmosis easily flows through the semi-permeable walls of a small departmental GIS lab. A well-endowed GIS center makes great publicity photos, but its practical access by faculty and students often rivals an assault on Bastille, guarded by unfamiliar and intimidating GIS-perts.

Assuming a balance can be met between efficiency and effectiveness of its logistical trappings, the issue of what GIS is (and isn't) still remains. Some of the earlier responses defined it as a mapping science; therefore it became the domain of the geography/cartography unit on campus. Other responses emphasized its computer and database underpinnings and placed it in the computer science department. More current definitions, however, spring from a multitude of applications in diverse departments, such as natural resources, land planning, engineering, business and health sciences.

The result is a patchwork of GIS definitions aligning with the separate discipline perceptions of its varied applications. This situation is both good and bad. It provides a context and case studies which resonate among selected sets of students. Unlike those introductory courses in statistics addressing the probability of selecting "a white or a black ball from an urn" (get real), application-specific GIS grabs a student's attention by directly relating it to his or her field of interest.

The underlying theory and broader scope of the technology, however, can be lost in the practical translation. While geodetic datum and map projections might dominate one course (map-centric), sequential query language and operating system procedures may dominate another (data-centric). A third, application-oriented course likely skims both theoretical bases (the sponge cake framework), then quickly moves to its directed applications (the icing).

While academicians argue their relative positions in seeking the "universal truth in GIS," the eclectic set of courses on campus becomes its tangible, de facto definition. It's at this level that a center of excellence in GIS is warranted—operating as a forum for exchange of ideas and expertise, not as a room full of hard and software items. Constructive discourse on what GIS is (and isn't) can be focused on the paradigms, procedures and people involved, rather than the trappings of the technology and whether "*dis'course is better than dat'course*" for the typical student.

Varied Applications Drive GIS Perspectives

(GeoWorld, August 1997)

(return to top of Topic)

Our struggles in defining GIS revolve less around its mapping and management concerns, than its application contexts and expressions. Although there are variations in data structures, a myriad of geo-referencing possibilities, and a host of methods to derive thematic mapping intervals, it is GIS's modeling component that causes most of the confusion and heated debates of what GIS is (and isn't).

We have been mapping and managing spatial data for a long time. The earliest systems involved file cabinets of information which were linked to maps on the wall through shoe leather. An early "database-entry, geo-search" of these data required a user to sort through the folders, identify the ones of interest, then locate their corresponding features on the map on the wall. If a map of the parcels were needed, a clear transparency and tracing skills were called into play.

A "map-entry, geo-search" reversed the process, requiring the user to identify the parcels of interest on the map, then walk to the cabinets to locate the corresponding folders and type-up a summary report. The mapping and data management capabilities of GIS technology certainly has expedited this process and has saved considerable shoe leather… but come to think of it, it hasn't fundamentally changed the process. GIS's mapping and management components are a result of a technological evolution, whereas its modeling component is a revolution in our perception of geographic space and spatial relationships.

This new perspective of spatial data is destined to change our paradigm of map analysis, as much as it changes our procedures. ***GIS modeling*** can be defined as the representation of relationships within and among mapped data (see figure 1). A geo-query, such as "all counties with a population over 1,000,000 and a median income greater than $25,000" is not a GIS model. It simply repackages and plots existing data that describe independent map entities. Modeling, on the other hand, derives entirely new information based on spatial relationships, such as coincidence statistics, proximity, connectivity and the arrangement of map features.

As depicted in figure 1, GIS modeling can take several forms. The two basic approaches concern cartographic and spatial models. Whereas ***cartographic modeling*** involves the automation of manual map analysis techniques, ***spatial modeling*** involves the expression of numerical relationships of mapped data. The former treats numbers comprising a digital map as simply surrogates for traditional analog map representations of inked lines, colors, patterns and symbols. The latter anoints digital maps with all of the rights, privileges and responsibilities of quantitative data, thereby forming a new map-ematical discipline.

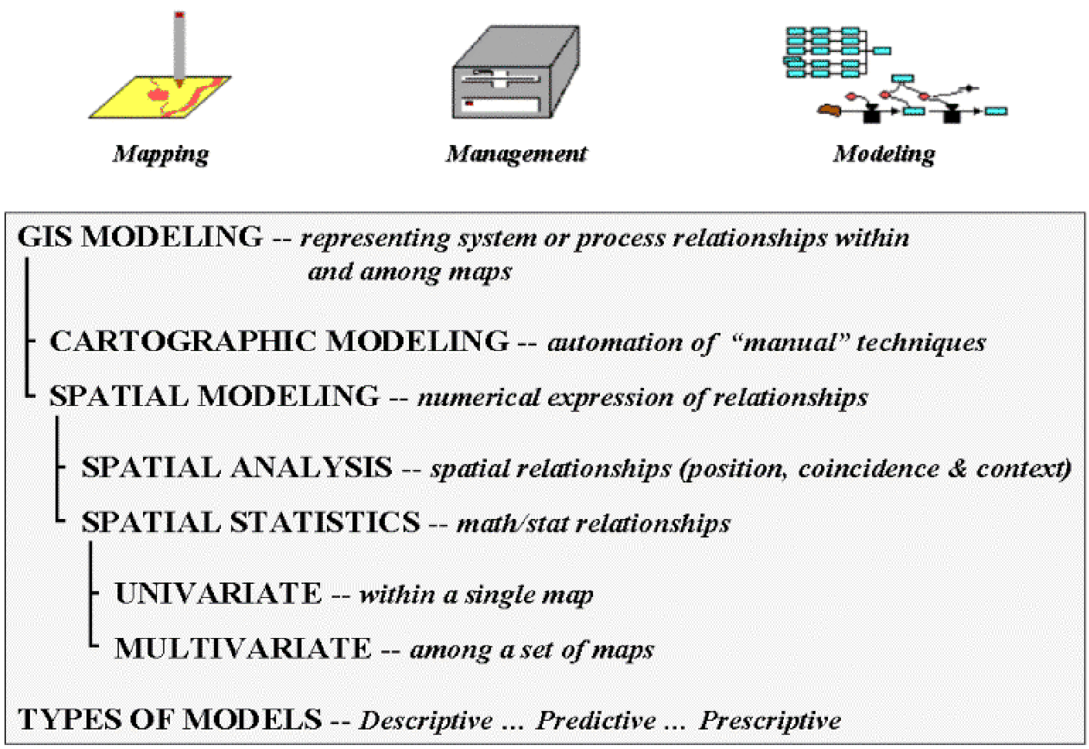


Figure 1. Various approaches used in GIS modeling.

The numerical treatment of maps, in turn, takes two basic forms—spatial statistics and spatial analysis. Broadly defined, ***spatial statistics*** involves statistical relationships characterizing geographic space in both descriptive and predictive terms. A familiar example is spatial interpolation of point data into map surfaces, such as weather station readings into maps of temperature and barometric pressure. Less familiar applications might use data clustering techniques to delineate areas of similar vegetative cover, soil conditions and terrain configuration characteristics for ecological modeling. Or, in a similar fashion, clusters of comparable demographics, housing prices and proximity to roads might be used in retail siting models.

Spatial analysis, on the other hand, involves characterizing spatial relationships based on relative positioning within geographic space. Buffering and topological overlay are familiar examples. Effective distance, optimal path(s), visual connectivity and landscape variability analyses are less familiar examples. As with spatial statistics, spatial analysis can be based on relationships within a single map (univariate), or among sets of maps (multivariate). As with all new disciplines, the various types of GIS modeling are not dichotomous, but identify the range of possibilities along a continuum of approaches. In addition, most applications utilize a combination of mapping, management and various types of modeling approaches in their solution.

In all cases, GIS applications involve spatial reasoning of complex systems, be they geo-business, ecological, or other processes. The GIS toolbox remains the same, however the applications dramatically change. These similarities and differences drive our varied perspectives of GIS technology and provide a framework for discussion of the paradigms, procedures and people GIS education needs to address… but discussion of the mix needs to be postponed to a later discussion.

Diverse Student Needs Must Drive GIS Education

(GeoWorld, September 1997)

(return to top of Topic)

GIS technology is "as different as it is similar" to traditional mapping and data analysis. Likewise, GIS education needs to incorporate unconventional concepts and approaches, as well as extending conventional ones—"business as usual" is out of the question. The diverse set of perspectives of GIS technology provides a useful framework for discussion of GIS education, as it relates to paradigms, procedures and people.

Fundamental to understanding GIS is the recognition that a computer map is a set numbers first, a picture later. How the data is encoded and stored is important, as well as an appreciation of geographic principles, such as coordinate systems and map projections, particularly for students emphasizing database development and production mapping. A basic understanding of computer environments and operating as well as database management skills, such as indexing, selection ladders, and macro language proficiency, are important, particularly for students emphasizing management and modeling of spatial data. These, and similar topics, represent extensions of exiting concepts of space and data analysis, adjusted for the digital mapping environment.

Several concepts, however, represent radical shifts in the spatial paradigm. Take the concept of map scale. It's a cornerstone to traditional mapping, but it doesn't even exist in a GIS. Map scale reports the "ratio of map distance to ground distance," assuming a specific map output product. In a GIS you can zoom in and out on a particular area, changing its "scale" at will—map scale isn't part of the GIS, but an artifact of the screen or paper display. However, the related concept of map resolution is fundamental to GIS as it identifies the level of detail (spatial, thematic, temporal and mapping) captured in a digital map. Just as it is a violation to superimpose paper maps of differing map scales, it is a violation to superimpose digital maps of varying resolutions—both cases result in pure, dense (but colorful) gibberish.

Similarly, combining maps with different data types, such as multiplying the ordinal numbers on one map times the interval numbers on another, is map-ematical suicide. Or evaluating a linear regression model using mapped variables expressed as logarithmic values, such as a PH for soil acidity. Or consider overlaying five fairly accurate maps (good data in) whose uncertainty and error propagation results in large areas of erroneous combinations (garbage out). It is imperative that GIS education fully embraces the quantitative aspects of maps and instills an understanding of its implications beyond the inked line and paper map paradigm.

The practicalities of implementing procedures often overshadow their realities. For instance, it's easy to use a ruler to measure distances, but its measurements are practically useless. The assumption that everything moves in a straight line does not square with real-world—"as the crow flies," in reality, rarely follows a straightedge. Within a GIS, distance (shortest straight line between two points) can be extended to proximity (by relaxing "between two points" to "among sets of points"), then to movement respecting relative and absolute barriers to travel (by relaxing "straight line" to "not-necessarily-straight route").

In practice, a 100 foot buffer around all streams is simple to establish (as well as conceptualize), but has minimal bearing on actual sediment and pollutant transport. It's common sense that locations along a stream that are steep, bare and highly erodeable should have a larger setback. A variable-width buffer respecting intervening conditions is more realistic.

Similarly, landscape fragmentation has been ignored in resource management. It's not that fragmentation is unimportant, but too difficult to assess until new GIS procedures emerged. Procedures, such as travel-time surfaces, *n-th* optimal path density, and data-surface modeling, are challenging old, limiting assumptions about spatial data and their relationships.

These new procedures and the paradigm shift are challenging GIS users and their educational needs. Potential users first can be grouped by their interaction with the technology, then by their situation. Three broad types of users can be identified: ***Application-centric*** (routine user, casual user and interactive user), ***Data-centric*** (data entry specialist, database manager, and system manager), and ***Procedure-centric*** (software programmer and application developer). In turn, these user groups can be further refined by their disciplinary focus (natural resource, business, engineering, etc.).

The diversity of users, however, often is ignored in a quest for a "standard, core curriculum." In so doing, a casual user interested in geo-business applications is overwhelmed with data-centric minutia; while the database manager receives to little. Although a standard curriculum insures common exposure, it's like forcing a caramel-chewy enthusiast to eat a whole box of assorted chocolates. The didactic, two-step educational approach (intro then next) is out-of-step with today's over-crowded schedules and the diversity GIS users. A case study approach with extensive hands-on experience provides better focus, but it puts a greater burden on individual instructors and facilities.

A potential user's situation has a bearing on GIS education. In the broadest sense there are two situations: traditional and non-traditional. The former group includes conventional students flowing through the K-12, undergraduate and graduate programs. In the long run, GIS exposure will appear throughout this pipeline. However, in the short run most students are frantically attempting to retrofit themselves. Traditional courses tuned to a methodical progression rarely fit their backgrounds and schedules (interests aside).

Although non-traditional students tend to be older and even less patient, they have a lot in common with the current wave of "out-of-step" traditional students. They have even less time and interest in semester-long "intro/next" course sequences. By default, vocational training sessions are substituted for their GIS education—"how to" replaces "what and why." The two estranged student groups, however, pose an interesting opportunity for partnering between industry and academia. The need for targeted short courses by both student groups suggests intensive offerings over weekends and vacation periods. The extended network of in-place instructional facilities provides the logistical setting, while collaboration between vendor and academic instructors provides the intellectual material.

A mixed audience of traditional and non-traditional students provides an engaging mixture of experiences. So what's wrong with this picture? What's missing? Not money as you might guess, but an end run around institutional inertia and rigid barriers. Adoption of GIS technology can't wait a generation for the normal flow through the educational pipeline. A "steady-she-goes" approach of the institutionalized education tanker needs turning… or have we missed the boat entirely?

Author's Note*: the first three sections of this series on GIS education is based on a plenary presentation made to the Sixth Annual MAGINE Forum, May 1 and 2, 1997, Lancing, Michigan.*

Turning GIS Education on Its Head

(GeoWorld, May 2003)

(return to top of Topic)

Now that GIS is in its fourth decade, some of the early mystery has been diminished. Simply displaying a map on a computer a few years ago was Herculean feat. Automatically hot-linking your vacation pictures to their exact location on map and having Aunt Julie in Winnemucca view them over the Internet wasn't even on the radar screen.

As much as its technological underpinnings have changed, GIS's learning environment and academic approaches seems to have evolved even more. In the 1970s, the mainframe computer kept students at least one glass window away from the machine and simply getting the proper "job control" sequence of punch-cards was a challenge. The 1980s ushered in interactive computing but the intellectual exchange has severely burdened by the din of competing systems, procedures, concepts and ideologies. GIS was maturing but still very much in its adolescence stage.

In the 1990s several factors converged—sort of a perfect storm for GIS education. Cantankerous workstations morphed into user-friendly PCs with power, GPS technology put direct access of "where" information literally in users' hands, data became ubiquitous via the Internet, and most importantly, GIS software emerged from its specialist's cocoon.

The early environments kept GIS in a backroom "down the hall and to the right." Its modern expression, however, enables users with increasingly diverse backgrounds to take the wheel. The splash of digital maps on the screens in the front offices are radically changing what spatial technology is (and isn't), who constitutes the GIS community and how educational curricula address this evolution.

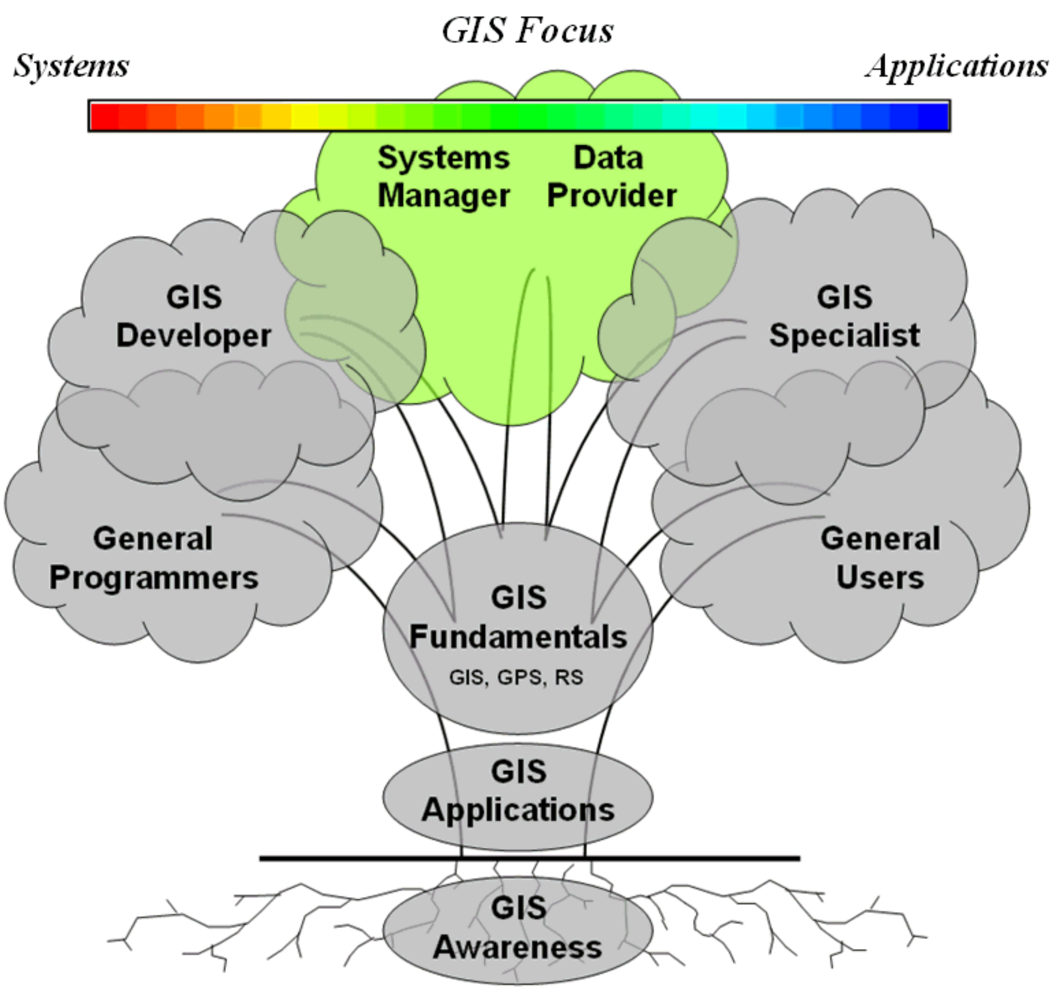


Figure 1. The GIS community encompasses a rapidly growing number of disciplines and diverse perspectives of what spatial technology is and isn't.

Figure 1 characterizes the GIS community as a tree with branches representing different activists. The left side membership is primarily focused on system design and development, while the right side emphasizes applications. To be fully effective, GIS curricula must recognize the increasingly diffuse character of the student pool and offer courses tailored to a variety of interests.

For example, the perspectives, skill sets and GIS goals of *General Users* are fundamentally different from those of *General Programmers.* In addition, the student pools likely reside in different subcultures on campus that rarely share a classroom. Spatial technology can serve as a common thread but the course work requires recognition of diverse backgrounds, interests and objectives.

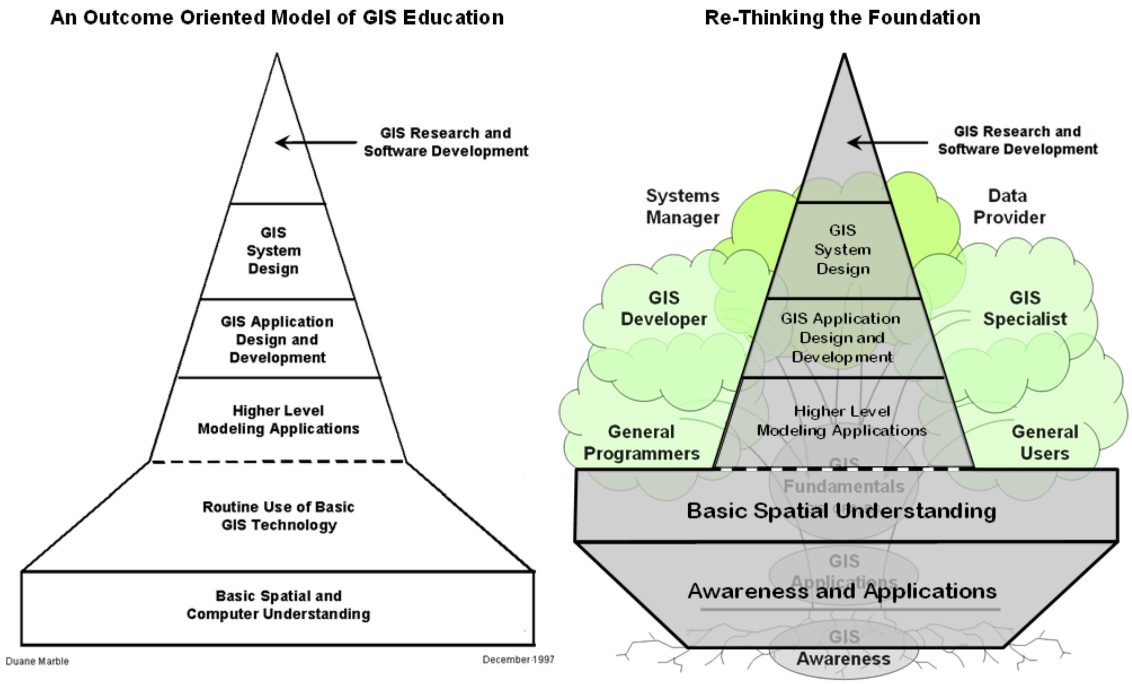


Figure 2. GIS education traditionally proceeds from basic spatial concepts and routine use through advanced applications and system design/development (after Marble, 1987).

Professor Marble with Ohio State University is a leading GIS educator who sees the situation from a slightly different angle (see Figure 2 and Author's Note). He identifies a pyramid with progressive levels of spatial skills and is concerned about the "…the great majority of persons who are 'educated' in GIS attaining competence only at the very lowest operational level." In addition, he sees minimal attention "…being paid in most programs to the education of individuals who desire to reach the higher levels of the pyramid."

These points are very well taken and reflect the evolution of most disciplines crossing the chasm from start-up science to a popular technology. Marble suggests the solution "…appears to be to devise a rigorous yet useful first course that will provide a sound initial foundation for individuals who want to learn GIS and that also make extensive use of GIS technology in its presentation." At the same time he recognizes that "…if we tell people that they cannot 'do' GIS without first taking several courses then I suspect they will simply ignore us."

So how can GIS education raise awareness and stimulate interest while instilling a sound foundation in the underlying concepts, procedures and considerations? It's at this point that my thoughts slightly diverge from Marble's. Whereas he is concerned with the "dilution of GIS education," I am just as concerned about generating awareness and stimulating new applications by casting the broadest net possible.

The right-side of figure 2 turns the early phases of GIS education on its head by suggesting that the "Basic Spatial" principles (e.g., geode, datum, projections, data/exchange, etc.) be presented after students are introduced to spatial reasoning concepts. This would mean that students are not initially confronted with mechanics, technical details and data principles but work with hands-on exercises that clearly illustrate and instill "thinking with maps."

Such experience wouldn't be a rice-cake flurry of "dog-and-pony show" applications (e.g., frog habitat modeling in Belize for geo-business students) but contain real-meat exercises using (and this is important) perfect data and procedures that demonstrate spatial concepts within student's own area of interest and expertise. While designing such materials is a piece-of-cake from a technical perspective, it means that the contextual structuring of the materials requires expertise outside of GIS.

That means that the next piece of the GIS education puzzle needs to come from a dispersed set of departments/colleges throughout campus— a sociologist here, a real estate professor there, an IT instructor around the corner (and the eye of newt if needed). The bottom line is that GIS-*perts* need to recognize that the field has grown beyond its original disciplinary boundaries.

The "up-side-down" approach suggests that the growing pool of potential new users are first introduced to what GIS can do for them and how it's different from traditional ways of doing things, then progress to the mechanics required for solo flights. GIS has grown-up and is rapidly becoming part of the fabric of society. Where and how far it is taken in the next decade will be determined, in large part, by an effective educational setting.

Author's Note: *See Marble, Duane F. 1997. Rebuilding the Top of the Pyramid: Structuring GIS Education to Effectively Support GIS Development and Geographic Research. Proceedings of the Third International Symposium on GIS and Higher Education [Online] Available at:*
http://www.ncgia.ucsb.edu/conf/gishe97/program_files/papers/marble/marble.html.

Author's Update: *(9/09) Duane Marble in a more recent thoughtful article entitled "Defining the Components of the Geospatial Workforce—Who Are We?" published in ArcNews, Winter 2005/2006, suggests that—*

"Presently, far too many academic programs concentrate on imparting only basic skills in the manipulation of existing GIS software to the near exclusion of problem identification and solving; mastery of analytic geospatial tools; and critical topics in the fields of computer science, mathematics and statistics, and information technology."
http://www.esri.com/news/arcnews/winter0506articles/defining1of2.html

This dichotomy of "tools" versus "science" is reminisce of the "-ists and -ologists" debates involving differing perspectives of geotechnology in the 1990's. For a discussion of this issue see Beyond Mapping III, Epilog, "Melding the Minds of the "-ists" and "-ologists." available at:
http://www.innovativegis.com/basis/MapAnalysis/MA_Epilog/MA_Epilog.htm#Melding_Minds.

Other related postings are at:

- http://www.innovativegis.com/basis/present/GIS_Rockies09/GISTR09_Panel.pdf, handout for the panel on "*GIS Career Opportunities*," GIS in the Rockies, Loveland, Colorado; September 16-18, 2009.
- http://www.innovativegis.com/basis/present/LocationIntelligence09/LocationIntelligence09.pdf , handout for the panel on "*Geospatial Jobs and the 2009 Economy*," Location Intelligence Conference, Denver, Colorado, October 5-7, 2009.
- http://www.innovativegis.com/basis/present/imagine97/, a keynote address on "*Education, Vocation and Enlightenment,*" IMAGINE Forum, Lansing, Michigan, May 1997.

(return to top of Topic)

(Back to the Table of Contents)